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656.

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INLAND TRANSPORTATION.—DISCUSSION ON PAPER No. 605.*

By C. W. RAYMOND, EDWARD P. NORTH and F. A. MAHAN.

C. W. RAYMOND, M. Am. Soc. C. E.†—Captain Mahan's paper raises many important questions of national and commercial policy which it is impossible to discuss adequately on this occasion. While fully recognizing the ability and literary skill with which he has treated the subject of inland transportation, I am compelled to dissent from many of his views.

The main foundation of his argument in favor of the construction and maintenance of artificial water-ways is the assumption that they furnish cheaper transportation than railways for heavy and bulky materials. This he endeavors to establish from a comparison of freight rates for grain on various railways and water lines, showing, he thinks, a decided economy in favor of the water transportation. For example, the average freight rates per bushel of wheat from Chicago to New York in 1891 were, by lake and rail, 8.53 cents, and by lake and canal, 5.96 cents, from which it is inferred that there is for the latter route a

* "Inland Transportation." By Capt. F. A. Mahan, Corps of Engrs., U. S. A. *Transactions*, Vol. XXIX, page 97.

† Major, Corps of Engrs., U. S. A.

saving in the cost of transportation of 2.57 cents per bushel. Supposing all the grain moved from Chicago to New York in 1891 to have been carried over the water-route, the writer considers that there would have been a saving of $3 208 500 in the total cost of transportation.

The fallacy in this method of comparison lies in the fact that it confuses the freight rate with the net cost of transportation, two very different things. The freight rate is simply the price paid for transportation. The net cost of transportation includes two principal elements—the toll for use of way, and the cost of transport proper. The toll for use of way covers the interest on the cost of construction and improvement and the cost of maintenance. The cost of transport proper covers the use, management and care of the vehicles and the expenses of traction.

In the railway freight rates quoted by the writer both these elements are included, while the water-route rates include the cost of transportation proper only. To make the comparison a fair one, the freight rate for the water route should include the toll for the use of way. I have not the data at hand to determine what this toll amounts to for the water route from Chicago to New York. M. Colson states that for the navigable ways of France the average cost of transport proper should be doubled to allow for this element.* If we apply this rule to the water rates quoted by the writer, what becomes of the economy of the water transportation?

The writer's views regarding the economy of inland water-transportation are, however, based, not only upon the statistics of our own country, but also upon the experience of other nations. He says:

"The water-ways of France and Germany also show economy of transportation when heavy, bulky materials are to be carried. The more the question is studied, the more desirable the use of water-ways becomes. It is evident by the great attention which many nations are bestowing on their navigable highways that there is something real, something tangible, in the economic results to be obtained by water-carriage."

Doubtless there is in many cases something real and tangible to be obtained by water-carriage, but it is certain that generally this tangible something is not economy of transportation. An analysis of experience in France seems to prove conclusively that between two given points the mean net cost of transportation is in general lower for

*Transports et Tarifs, par C. Colson, Ingénieur des Ponts et Chaussées, etc., page 224.

the railway than for the water-way. Moreover, it has been asserted by high authority that, owing to its advantages of speed, regularity and general convenience, transportation by rail is preferable to transportation by water, even when the cost of the former exceeds that of the latter by about 20 per cent.

If these views are correct, it is hardly necessary to adopt the author's theory to account for the temporary abandonment of artificial water-ways in this country. This theory is briefly as follows: When railways first came into existence the people were carried away by the marvelous results that were predicted and their feelings overpowered their judgment. The capabilities of the canals had not been fairly tested. Under the influence of this sentiment, the railway system was rapidly developed, the best ability of the country being enlisted in its service. In addition to this sentimental obstacle, the canals had to contend against the constant and vigorous attacks of the railway managements, which, although composed of the ablest men in the country, become "ignorant and prejudiced" when water transportation is in question. The canals were not improved or developed so as to utilize their advantages to the full extent; and, unable under these circumstances to compete with the railways, they were abandoned, or, if maintained, they steadily lost ground as carriers of freight.

This is not the way I read the history of American transportation. When the railway was introduced, the people, with their usual sagacity in business matters, saw that the new method of transportation presented advantages which artificial water routes did not possess. It was available at all seasons of the year; it saved time; it was adapted to both light and heavy freight and to passenger traffic; it furnished regularity of service; and, finally, it gave the lowest net cost of transportation. The people could not be fooled into the idea that they could reduce the price of transportation by taking part of it out of one pocket and part out of another. They developed and improved the railways at the expense of their own earnings and because they believed it would pay. They did not develop and improve the canals because the earnings of the latter would not bear the expenses of development and improvement, and because they thought it would not pay. They neglected or abandoned the canals because they rightly believed that under the existing conditions of the transportation of the country any other course would be a financial absurdity.

I am strongly impressed with the idea that, although the American people may lack the wings of theory, they somehow or other generally manage to arrive.

I cannot agree with the writer that the abandonment of the canals of Pennsylvania "partook of the treachery of Judas." For my part, I can see a canal abandoned and in decay with more equanimity than I can see it foolishly and uselessly operated at the expense of the people. Incidentally it may be remarked that nine of the Pennsylvania canals are still operated, although doubtless they cannot be considered financially successful if cost of construction is taken into account.

Does it follow from all this that the development and improvement of inland water transportation is inadvisable? By no means. There are many circumstances in which such a policy is of great benefit to the public interests. In some cases natural water-ways exist which may be made available and convenient for navigation at a cost which will give a net cost of transportation for heavy freight sufficiently low for competition with the railway lines. The improvement of such water-ways is generally wise on economical grounds. In some other cases, even where improvement involves a net cost of transportation greater than that obtained from the railways, it may be sound public policy to improve a water-way at the public expense. For example, such a route may be needed for a heavy traffic which could not otherwise be maintained and which may be of great importance to the manufacturing or other interests of the country. Such a route again may be desirable to prevent the diversion of heavy transportation to the sea to some existing water-route in a foreign country. Finally, it may perhaps be wise in some cases to maintain water-routes at the public expense to control freight rates and as a check upon railway combinations; but if this is the only object of construction, the question arises whether the Government would not be equally justified in constructing and maintaining a competing railway for this purpose.

It is important to observe that the desirability of improving the routes of water transportation in any country increases with the density of the population and the development of the railway system. In a country which is not densely populated the business of transportation can generally be handled by railways more economically and satisfactorily than by water-ways, unless indeed there are natural water-ways which can be utilized at small expense. There are, however,

natural limits to railway expansion; and when a country becomes so densely populated that its transportation business cannot be conveniently handled by railways, it may become a matter of high public policy to utilize the water-courses to their full extent. In France and Germany this condition of things seems to have been nearly reached. According to Colonel King,* France in 1885 had a population 13 times denser than that of the United States, with 1 mile of railway to 11 sq. miles of territory. The population of Germany was 15 times denser than the United States, with 1 mile of railway to 9 sq. miles of territory. It will be readily understood that the question of the comprehensive development of a system of water-ways stands upon a very different basis in these relatively small, compact and densely populated countries than in our own extensively and sparsely populated country. Even in these countries the wise limit for the extension of water transportation is still the subject of earnest consideration and debate; and in France, as is shown by the author himself, the improvement of water-ways was seriously neglected for a period of 25 or 30 years after the introduction of railways.

The author is in error in supposing that no systematic plan has ever been proposed for the development of the water-ways of the country. In fact such a plan was very fully considered by the Senate Committee on Commerce, and was the subject of very elaborate investigations and reports by the Corps of Engineers from 1874 to 1881. These reports now repose in their appropriate pigeon-holes, awaiting the time when the conditions of the country justify the serious consideration of such schemes; a time which, in my opinion, has not yet arrived. A special committee of the Senate for the consideration of this subject still exists.

In fact the method of procedure still followed in this country, to which the author so strongly objects—the method of considering each project for a river and harbor improvement upon its own merits, with special reference to existing needs and conditions, and with incidental reference only to the probable necessities of the distant future—is the only method which can be wisely followed for a long time to come. A comprehensive scheme of improvement at the present time is simply a paper scheme. It may be of interest to theorists as a hydraulic diversion, but it can be of no present value to practical men who are seeking results of immediate benefit to the country.

* River Transportation and the Muscle Shoals Canal.

Finally, I think the author unintentionally misrepresents the character and history of our system of conducting public works, and fails to recognize its very remarkable progress and results. Although considerable work of river and harbor improvement was executed at the expense and under the direction of the General Government previous to the Civil War, a system for such improvements can hardly be said to have existed. The present system may, I think, be considered to have originated about the year 1866. A system for the projection and execution of public works cannot be improvised, especially under a representative form of government, but must be slowly developed, in conformity with the character and needs of the country; and it can only be perfected by long experience. Accordingly, it is not a matter for surprise that at the commencement of the system and during the early years of its history it should present grave defects, and serious obstacles to its improvement should be encountered. Some of these obstacles and defects may be briefly noticed.

1. The right of the General Government under the Constitution to execute works of river and harbor improvement was very seriously questioned. Even admitting this right, there was great difficulty in establishing the limits of the powers and duties of the Government and those of the States. For example, the Constitution places under the control of the General Government certain matters in which the interests of the whole country are directly involved, leaving the management of purely local affairs under the control of the States. But there seems to be no direct provision for the control of matters in which two or more States are involved, to the exclusion of the rest of the country. If, for the purpose of illustration, we suppose it to be desirable to construct a comprehensive system of levees along the banks of the Mississippi for the purpose only of protecting the adjacent lands from overflow, and without reference to the needs of navigation, it would be difficult to find authority for the execution of the work by the General Government; and yet, in the nature of the case, it is a work which cannot be efficiently accomplished by the States interested.

As regards this question, it is important to notice that there is a marked distinction between the improvement of maritime ports and their approaches and the improvement of routes for inland transportation. The General Government derives a large revenue from the duties on foreign commerce, the collection of such duties by the States being

expressly prohibited. It therefore seems reasonable that the General Government should bear the expense and assume the duty of creating and maintaining facilities for communication with foreign countries. The improvement of inland navigation by the General Government to facilitate commerce between the States and to regulate rates of transportation by interfering with natural development under competition is an entirely different question, and one which is still worthy of serious investigation and thoughtful discussion.

2. Theoretically the improvement of a harbor or water-way promotes the general commerce of the country and is therefore a benefit to the whole nation. But our country extends over so great an area, and its commercial interests are so diversified, that practically each improvement is a much greater benefit to its immediate locality than to the rest of the country. The extent of the improvements desired being very great and the amount which can be obtained from the Treasury in any one appropriation being necessarily limited by financial and political considerations, it naturally follows that there is a lively competition between the congressional representatives of different parts of the country to obtain provision for improvements in their own localities. I know no way in which such competition can be prevented and I do not think it ought to be prevented if it could be. It seems to be the best if not the only way to insure due consideration for the interests of every part of the country. But in the early days this competition resulted in bargains between members of Congress by means of which unwise schemes of improvement, which doubtless involved a waste of the public money, were occasionally adopted. The extent of this evil has been very greatly overestimated, the amount of money unwisely expended under the orders of Congress being very much smaller than is generally supposed, even in the early years; but the evil did undoubtedly exist. At that time our system was altogether too "comprehensive!"

3. As a very large number of improvements were demanded, and as the total amount available for appropriation was limited, it became the custom to scale down these amounts allotted to the various works frequently below the limits of profitable expenditure. Thus the total cost of the improvements was often greatly increased.

4. At the commencement of these works of improvement after the termination of the Civil War, the number of Government engineers

who had much experience in conducting such works was comparatively small. The work of the Corps of Engineers during many preceding years had been principally of a military character, and the methods of administration and experience of the corps were better adapted to military than to civil engineering. The officers of the corps were carefully selected from the graduates of West Point just as they are at the present time, but no provision was made for training them to design and execute civil works, except the elementary course of instruction at the military academy. Under the circumstances it was inevitable that for awhile mistakes should occur, and it is not surprising that Congress did not place full confidence in the advice and opinions of inexperienced engineers. Undoubtedly the committees of Congress did in these early days occasionally formulate opinions on purely technical subjects which they were not professionally qualified to consider, and thus to some extent "usurp the functions of the executive," as the author charges.

If time and space permitted it would be interesting to trace the development and improvement of this system through the past quarter of a century; but I must confine myself to a brief description of the system as it now exists. The acts of Congress which provide the funds and regulate the execution of works of river and harbor improvement by the General Government are framed by two committees—the Senate Committee on Commerce and the House Committee on Rivers and Harbors. The Senate Committee consists of 13, and the House Committee of 15, members. They are carefully selected, so as to represent all the commercial interests of the country. The majorities of these committees are composed of men who have had long experience in the consideration and direction of legislation for public improvements. The Chairman of the Senate Committee has had a continuous experience of 22 years, and the average length of service of the members is, I believe, at least 12 years. The Chairman of the House Committee has had a continuous experience of 12 years, and another member has had 18 years of continuous service. Although there are more changes in the House than in the Senate Committee, it contains, I believe, only five or six new members, the average length of service of nine members being about eight years. These are the men with reference to whom the author asks the question: "How can legislators, who rarely retain their seats for more than one or two terms, act intelligently on such matters?"

These committees are, to all intents and purposes, commissions to consider and recommend projects for works of public improvement. They exert an influence upon legislation which could not possibly be exerted by commissions constituted in any other way, and they maintain the closest connection with the people and the States, a matter of great importance under our form of government.

The information upon which these committees base their action is furnished by the annual reports of the Chief of Engineers and the accompanying reports of officers in direct charge of works, which are prepared with great care in accordance with a carefully devised system, and which include commercial statistics for each locality. In cases of importance, special boards or commissions are organized on which civilians are sometimes associated with the Government engineers. In other cases permanent commissions have been created for the continuous investigation and direction of important projects. When further information is required, special reports on specific points are called for, and the committees frequently pursue their investigations through personal conferences with the Chief of Engineers, the division engineers, the local engineers, and persons interested in the work under consideration. Individual members and subcommittees sometimes personally visit the works. Legislation is almost always finally determined by a conference of members from both committees.

The system now adopted to prevent unwise expenditure of the public money is as follows: The law provides for certain preliminary examinations to be made by the district engineer or some other engineer detailed for the purpose. This engineer and his superior, the division engineer, are required to report to the Chief of Engineers whether, in their opinion, the harbor or river under examination is worthy of improvement by the General Government, giving the facts and reasons on which their opinions are based, including the present and prospective demands of commerce. They are also required to submit estimates for the cost of survey, and the preparation of plans for improvement. The Chief of Engineers is required to submit these reports, with his own views, to the Secretary of War. The latter is required to submit them to Congress, where they are printed for the information of the committees and the other members.

After the consideration of these reports, if Congress so orders, the survey is made and the project is prepared; but no work can be done

until Congress has duly considered the survey and project, and has authorized the work and appropriated funds for its commencement. This method of procedure has resulted in the rejection of a great many doubtful schemes, many of which doubtless would have been undertaken in earlier years. In recent river and harbor bills the percentage of unwise appropriations (if there are any) is probably as small as can be obtained under any human system.

The evils resulting from inadequate appropriations have been met by the adoption of the system of so-called continuous contracts, whereby the making of contracts for complete improvements to the full extent of the estimates is authorized, the work to be paid for as appropriations may from time to time be made by law. This system is still an experiment, but it has already been adopted for about seventeen of our most important and expensive works.

As regards the formation of opinions on purely technical subjects, the committees are now almost wholly guided by the advice of Government officers or other professional engineers. Looking back to the state of our engineering knowledge and experience twenty-five years ago, the exercise by congressmen of independent judgment in technical questions does not seem to me surprising. The general confidence which the committees now repose in the officers of the Corps of Engineers rests upon the fact that for a quarter of a century we have had practical and generally successful experience in the conduct of public works; that our methods of administration have been perfected and adapted to the system; that our theoretical instruction has been increased by a three years' course of training at the Engineer School, in addition to the four years of preparatory education at West Point; and finally (and most important of all), that our opinions are believed to be unbiased and impartial, and are confined strictly to professional questions, except when we are directly required to report upon questions of public policy.

But would it be an improvement if these committees were partly composed of professional engineers? In my opinion, most emphatically, no. The members of the committees have all the ability and knowledge necessary to fully understand any project the engineers may lay before them. They do not pretend to be engineers, and therefore they rely on the Government engineers for the solution of technical problems; but in practical questions of finance, commerce and public

policy, they are, as a rule, vastly superior to the engineers. On the other hand, if a Government engineer should advance an uninvited opinion upon a question of public policy, he would not only violate a well-recognized principle of professional etiquette, but he would disobey positive orders. The established rule and custom of the Corps may be illustrated by the following quotation from the general order giving instructions for the preparation of the annual reports for this year:

"The laws do not call for opinions as to the propriety and expediency of making appropriations; but they do require facts, both as to the cost of works and as to the commerce interested, in order that Congress may determine the question whether the general commerce of the country will be promoted by the several works of improvement."

It is this clear division between the legislative work of the committees and the professional work of the engineers (a division which seems to be growing sharper year by year) which I consider the most admirable feature of our system.

Looking back over the past quarter of a century at the results attained, not only in the improvement of our executive and legislative methods, but also in works of improvement actually accomplished, I feel that the United States has no reason to be ashamed.

In conclusion, I desire to express my high opinion of the character and ability of the congressional committees in charge of this subject. For some years past I have been frequently associated with these committees and their individual members, and their patience and industry in investigation, and the general wisdom of their decisions, has won my respect and admiration. Commissions for directing public policy in river and harbor works, better adapted to the needs and conditions of our own country, and more thorough, efficient and intelligent in the execution of their work, could not be desired.

EDWARD P. NORTH, M. Am. Soc. C. E.—Referring to Captain Mahan's very valuable paper, "Inland Transportation," I wish to call attention to the assertion, "Efforts are made to improve certain streams, but each stream is treated simply as a problem in hydraulics and not as a part of a problem in commerce or transportation," and to cite in that connection the case of the improvement of the River Main from Frankfort to the Rhine, about 22 miles.

The freightage on this river, which had a governing depth of less than 3 ft., fell, through the competition of the railroads, from 492 000 tons in 1840 to an average of less than 10 000 tons for the years 1880–

82, when it was decided to improve the stream. Although the governing depth in the Rhine is only 6 ft., the German engineers decided to have a depth of 8½ ft. on the miter-sills of the locks and completed the work as far as the construction of the dams, by-passes and locks in three and a half years, though the full prism excavation was left for a year or two, and the locks have since been lengthened from 246 to 1 165 ft.

The great increase of traffic to Frankfort is shown in the following tables taken from the "Year Book" of the Frankfort on the Main Chamber of Commerce for 1892, viz.:

Through the canalization of the Main and the harbor improvements, the freightage of the Main, exclusive of rafting, has increased as shown below:

Years.	Tons.	Ton-Kilometers.
1880–82	9 442	311 586
1887	494 193	15 352 452
1888	696 759	20 551 352
1889	939 446	29 159 283
1890	1 129 039	34 807 411
1891	996 919	30 239 351
1892	1 204 533	36 863 819

Attention is called in the "Year Book" to the fact that the ton-kilometers on the Main have increased from 1882 to 1892, 118 times. That this increase of river traffic has not been at the expense of the railroads, is shown by the subjoined table:

The freightage by railroad and water in Frankfort, without transit and raft traffic, was as follows:

	Water and Railroad. Tons.	By Water. Tons.	Percentage.	By Rail. Tons.	Percentage.
1884	1 014 519	150 514	14.8	864 005	85.2
1885	1 047 845	150 805	14.1	897 040	85.9
1886	1 088 047	155 957	14.3	932 090	85.7
Average, 3 years	1 050 137	152 425	14.4	897 712	85.6
1887	1 373 691	360 063	26.2	1 013 628	73.8
1888	1 748 733	526 798	29.6	1 231 935	70.4
1889	1 911 758	577 610	30.2	1 334 148	69.8
1890	2 103 171	697 351	33.1	1 405 820	66.9
1891	2 045 268	577 165	28.2	1 468 103	71.8
1892	2 211 601	709 118	32.0	1 502 483	68.0
Average, 3 years	2 120 013	661 211	31.2	1 458 802	68.8

It will be noticed that, comparing the two three-year periods, the increase of all freightage was nearly 102%; that by water was 333.7%, and by rail, 62.5%, but the aggregate increase by rail was one and three-quarter times greater than that by water. This is possibly the most successful instance of river improvement on record, taking both the time in which it was made and results into consideration.

In contrast to this we might instance the Tennessee River, which in the main stream and its tributaries presents a length of about 1 000 miles that under improvement would be available for navigation. The Muscle Shoals, 255 miles from the Ohio, have been under improvement since the General Government gave the States interested a land grant, in 1827, by the aid of which a canal of insufficient length, but with 6 ft. on its miter-sills, was completed, but afterwards abandoned. Since 1871 the improvement of this river has been under the direction of the General Government, and according to an article in the *Railroad Gazette* of November 14th, 1890, $3 112 500 had been appropriated up to that time, "and the interest account compounded semi-annually, at 5% per annum, amounts to $2 145 300, or about two-thirds of the cost." At this time I believe the canal had not been used commercially. This computation of interest was probably made on the supposition that the expenditures had been uniformly distributed. In the case of the Main, such interest account, on the same supposition, would have been only about 10% of the cost.

There is also another noticeable difference between the practice on the Main and that on the Tennessee. The depth on the miter-sills of the locks on the Main is 37.5% greater than the governing depth in the Rhine, to which the Main is tributary. This allows navigation to Frankfort by large boats that can be used only in high water, and is a strong incentive to further improvement of the Rhine itself. On the Tennessee, however, the depth on the miter-sills is for the present canal only 5 ft., instead of 13, or more, as would apparently have been adopted if the same views as to the value of large and powerful boats had governed the engineers of both countries. As the navigation past the Muscle Shoals is in part through a trunk, by-passes are not available, so that the through traffic is restricted to boats of 5-ft. draft. Such boats lack the capacity necessary for cheap freights, nor are they powerful enough to tow barges in high water.

Considering the length of the Tennessee and its affluents, with the

potential wealth of the valley drained, this does not seem a valuable issue of a study in hydraulics, and as a part of a river system over 15 000 miles in length it must be of less value to the transportation interests than to those rigorous economists who hold that it is cheaper to burn the steamboats on the Mississippi and its affluents than to expend money in river improvements.

There seems no other valid reason for expending money in river improvements, except a fair commercial expectation of increasing transportation facilities. With our present machinery for production there are commodities enough in the world, and the true benefactor is he who reduces the cost in time and money of assembling the raw products of manufacture and their distribution to consumers. For, under all circumstances, gains made by, or through, transportation are as inimical to the interests of a country in which they are made as gains made through reductions in the pay of laborers; as the cost of transportation must be taken in some ratio from the resources of both producer and consumer. Our wonderful record as producers and consumers—a record which shows that with 65 000 000 out of 1 500 000 000 inhabitants of this world, the people of the United States produce and consume over one-third of the iron, cotton and copper, and consume about a quarter of the wool and sugar produced – is greatly due to the fact that we have been reducing the cost of transportation per unit as no other people have, and at the same time bringing the producer and consumer nearer together, and that they both have secured larger returns for their expenditures of labor and money.

It is remarkable that as the producer and consumer have been brought nearer together, both the volume of freight and the ton mileage has increased. At the same time, the net earnings of our railroads have not been materially decreased. In fact, in some instances, they have been increased. An investigation made, preparatory to presenting a paper to the Fifth International Congress on Internal Navigation, "Notes on the Relations between Railroads and Water-Ways in the United States," showed that in the case of seven trunk lines, viz.: the Boston and Albany, the New York Central, the Erie, the Pennsylvania, the Pittsburgh and Fort Wayne, the Lake Shore and the Michigan Central railroads, the average freight rate per ton-mile fell from 2 cents and 9 mills in 1865 to 6.8 mills in 1890, and that the average net incomes of these seven trunk roads increased from 20.207% in 1865

to 31.95% in 1890, with less than one-quarter of the receipts for like services in 1890 than in 1865. And the average values of the stocks of these seven companies was virtually the same at the two periods, although their stock had been increased by 236%, and the bonds by 193%, in the interim.

It will be immediately seen that these roads are parallel to, or in continuation of, the freight rate through the Great Lakes. This reduction of freight rates to 24% of what they had been 25 years before, with the consequent national prosperity, was more due to the competition of the water route than to any other one influence, if not than to all others. The above-mentioned railroads were competing with the most capacious water route of the country. The great reductions in railroad freight rates were almost invariably inaugurated on these lines, and have passed to all the roads of the country; these trunk lines, at least, have increased their net earnings. In this instance, to borrow Captain Mahan's apt quotation, we have scattered and increased our gear through the great industries rendered possible by the low freights. An insufficient improvement of a water-course may, however, attack the money invested in a parallel railroad by reducing freight rates just enough to diminish net earnings without reducing the charges enough to develop greater production. This is the case of the man that withholdeth more than is meet, but tendeth to poverty.

Our system of internal navigation, on the whole, however, in spite of the development on a few of the main lines, can, as Captain Mahan observes, scarcely be called satisfactory. The minor streams are unimproved; the 15 000 miles of water-courses in the Mississippi Valley are unconnected with the nearly 3 000 miles of other rivers emptying into the Gulf on the one hand, and inadequately connected with the waters of the Great Lakes on the other. The production of the Saskatchewan Valley should be made tributary to the prosperity of Duluth, through the Red River of the North, and a competent canal. At the same time, both the lake and river systems of the Interior should be tied together and with the waters running into the Atlantic by waterways fitted to pass large traffics. These works would distribute the advantages of cheap freights over nearly all of our country to the great increase of employment and values.

Our experience with the Inter-State Commerce Commission shows the futility of trying to reduce freight rates by prohibitive legislation,

or at the command of a select body of men who are supposed to possess special fitness for the purpose. It might be violent to say that this commission, as soon as it was fully organized and in working order, succeeded in arresting the decline in freight rates which had been virtually continuous for 23 years. But, as a matter of fact, this decline was then substantially stopped. And apparently we have no insurance against following the example of Great Britain in freight rates—viz., no amelioration in the charges for 38 years—except through a radical improvement of our water-ways.

If this contention is even partially accepted it must be admitted that a careful study of the problem should be made by a commission fully competent, both by technical and commercial knowledge, to deal with a question that has so much influence on our prosperity. In the discussion following the reading of Mr. Corthell's paper, "The South Pass Jetties—Ten Years' Practical Teachings in River and Harbor Hydraulics," I recommended (*Transactions*, p. 243, Vol. XV) a report by a mixed commission, consisting of, say, three civil and three military engineers, with four persons interested in the commerce and industries of the locality, as precedent to an appropriation for the improvement of a stream or harbor, and that Congress should make the appropriation necessary for the completion of the work, so that it could be conducted with the speed necessary for economy. One part of this recommendation, viz., as to appropriations, has in some instances been adopted by Congress.

The very full and lucid paper contributed to the Engineering Congress of the Columbian Exposition, 1893, by M. l'Inspecteur-Général des Ponts et Chaussées Guillain,* recounts an error that is probably irreparable in planning the improvement of the French rivers and canals. Yet every question was apparently fully considered, and a judicious decision arrived at as to all except one. A scientific system of routes has been selected, connecting the different river valleys and also forming great through routes for transportation; the size of the locks has been (except on the Seine between Montereau and Rouen) made uniform, so that when the improvements are finished a boat loaded on any of the canals of France can reach the frontiers and most of the seaports. And this has resulted, on the canals improved, in a gain in kilometric tonnage of 109% between 1876

* *Transactions*, Vol, XXIX, page 1.

and 1891. And M. Delaunay-Belleville, in his paper presented at the Fifth International Congress on Inland Navigation, says that the augmentation in kilometric tonnage has been 48% for navigation, as compared with 9.3% by railroad, for the ten years ending with 1890.

The error in judgment, and apparently the sole error, made in planning this system of improvements was that the size of the boats is rigorously limited to 300 tons, except as to the Seine below Montereau, where boats of 1 000 tons may pass. These gains in water-borne traffic were made against the highest freight rates collected in any manufacturing country except Great Britain, and most of the canal traffic of France would be transferred to the railroads if their freight rates were no higher than those charged in this country. This is a very serious matter for France, for, if she reduces the freight rates on her railroads when they fall into the hands of the Government, she will impair or destroy the money invested in the canals.

It is a doubly serious matter for France, as the standard size of locks on the improved German water-ways pass boats of 800 tons. So that, unless France gives her manufacturers low railroad freights, which will destroy her investment in inadequate water-ways, she will be still further left in the race, through the cheaper internal freights of Germany. "It is possible to raise money in Europe for new guns, but not for new locks." Blame for the adoption of 300-ton boats on the French canals has not, to my knowledge, been located; but it does not seem possible that boats of that size for a maximum could have been selected if forwarders by water and presidents of Chambers of Commerce had been freely consulted, and their advice had carried due weight.

It is unpleasant to differ from Captain Mahan in his estimate as to the values of legislative and executive judgment. But whether the present capacity of French water-ways is the result of executive and administrative judgment coercing the legislative or not, he will remember that of the five vetoes of River and Harbor bills by various chief executives, four were strictly political vetoes, while the last and only one since 1854 was not in any sense a partisan proceeding, but was by one who thought he believed what the agents of railroads and bankers assured him he did believe. The veto was against the traditions of the party to which the vetoer belonged, and was rewarded by the claque of newspapers which has so long and vigorously opposed freight

reductions, and so far as he was able by this veto he stopped the reductions in freight rates then in progress. Our legislators have made no such mistake.

Nor is the Corps of United States Engineers entirely without members who, to adopt another of Captain Mahan's quotations, "think they think what they are taught," and insist on making improvements which do not improve, and fail to exceed in gravity the mistake of the French only through the fact that their mistakes are made in a country rich enough to buy both new guns and new locks. Possibly they are too much influenced by the fear that some man or locality may make money through the proposed improvement, a fear that seems easily implanted in breasts of a certain order by those in the present enjoyment of profits. A blending of such conservatism with the business element of the locality sought to be served by the appropriation could hardly fail to be beneficial to the interests of the country.

It is suggested, in conclusion, that public opinion is more easily enlightened by object lessons than by arguments. Disseminating knowledge of the fact that freight carried on the lakes during the census year cost less for transportation by $135 000 000 than an equal ton-mileage by railroad, and that that sum is equivalent to a dividend of 66% on the total expenditures by the general Government for the improvement of all rivers and harbors, has countervailed a great deal of newspaper mendacity. As a result, General Poe found enthusiastic support to his request for immediate money enough to deepen the Lake channels to 20 ft., but it is doubtful if an appropriation for 17 ft. in depth would have passed so quickly. If the administrative officers of our Government will propose improvements which by their capacity and convenience will cheapen transportation over large areas and develop increased production, they will call attention to the beneficence flowing from the recommendations of broad-minded men, those who really influence the great powers of Nature to the service of men; but a recommendation to increase the depth of a 10-ft. river to 11 ft. will develop no enthusiasm.

Captain F. A. Mahan.—Major Raymond seems to assume that I have confused the freight rate with the net cost of transportation, because I omit to make a specific distinction between the cost of carrying and the cost of construction, improvement and maintenance

of the way. Perhaps I took too much for granted as to familiarity with the figures of the Erie Canal which serves as my gauge in speaking of canals.

Up to the year 1882, when tolls were done away with on the Erie Canal, the receipts of various sorts amounted to $127 815 823 47. The cost of construction and maintenance was, up to the same year, $80 341 767 87, leaving a balance of $38 374 055 60. Improvements are evidently included under the cost of construction, to judge by the figures under this head. The items of construction and maintenance during the six years from 1886 to 1891, inclusive, amount to $6 812 731 50, an average of $1 135 455, or about 3% of the excess of the receipts over expenditures. Hence the investment of the above-mentioned excess at 3% would have given the funds necessary to carry on all the work which has been done during the past few years. This use of the earnings of the canal is a perfectly legitimate business transaction, and on this basis the tolls could be done away with and the canal be made free. In other words, the State pays the tolls for the use of the way out of past profits.

I do not agree with Major Raymond when he says "they (the people) did not develop and improve the canals because the earnings of the canals would not bear the expenses of development and improvement, and because they thought it would not pay." So far as I am aware, the canals of the State of New York are about the only ones which have been kept up at all, and on the Erie Canal alone can the canal experiment be said to have been fairly tried.

It may be objected that I make no allowance for stockholders' profits, if this term may be used. This is found in the increased valuation of property, in the growth of cities, in the general development of the interests of the State and its people. The Erie Canal must be deemed a success, and a marked success, from all these points of view.

As for the saving of time by rail I must say that it is not so great as many people suppose. I remember that when I was in charge of the work at Buffalo it took as long to send cement by rail from New York to Buffalo as it did to send it by canal, unless it were sent by fast freight and extra price paid therefor.

Whether the railway gives the lowest net cost of transportation is a question which is not at all settled in my mind on certain classes of freight. Railway transportation cannot compete with transportation

on the ocean, the great lakes, the sounds, or the large rivers. That, I believe, is universally admitted. A stream nearly dry during one-half of the year, and frozen over during the other half, could not compete with the railway. Between these two extremes there is a water-way which will carry as economically as the railways, and even more so. The question then is, can an existing canal be improved so as to reach this condition? Some can, I trow; some cannot.

Major Raymond mentions my speaking of the neglect of the improvement of the French water-ways for a period of 25 or 30 years after the introduction of railways, but he refrains from mentioning the extraordinary development of these water-ways since the limitations and uses of railways are more fully understood.

If I have misrepresented in any way "the character and history of our system of conducting public works," it is certainly unintentional. I fully recognize the immense progress and the remarkable results obtained by the corps of which Major Raymond and myself have the honor to be members. And yet I cannot but believe that the work of the corps would have been far more successful had more attention been paid to its advice and recommendations, or if the corps had been called on to prepare extensive projects into which technical details enter largely.

I shall not attempt to follow Major Raymond further, as he has wandered rather afield from my subject, in order to correct, apparently, a false impression which he seems to fear I have caused. For this I thank him. But I will not yield to him in doing honor to the corps to which we belong.

Mr. North's discussion of my paper seems to reinforce my arguments. At the same time he differs with me on some points, *e. g.*, the value of legislative and executive judgment. When I spoke of the executive I meant not the President, but the offices of the executive departments. I maintain now that the executive officers of the Government have far better judgment of technical problems and details than Congress possibly can have, for the simple reason that they are constantly handling such matters and are giving daily and increasing thought thereto. For example, I hold that the Chief of Engineers and his officers are far better able to decide how the improvement of a harbor or of a basin of a river should be carried on than any congressional committee can be, and *a fortiori* than Congress as a body. Con-

gress can best decide whether such and such works may be done as matters of public policy, but the details can best be handled by the executive.

"That Congress should make the appropriation necessary for the completion of the work, so that it could be conducted with the speed necessary for economy" is a remark which has been repeated over and over again in the reports of the Chief of Engineers. For more than twenty years have I seen attention called by one officer or another to the inefficient methods of making appropriations, but apparently without result. To be sure, appropriations of a smaller amount are now made sometimes, and authority is given to contract for considerably greater amounts, but there is no promise or guarantee, expressed or implied, that the funds will be forthcoming when needed to meet the Government's obligations.

It happens, unfortunately, that our executive or administrative officers may not propose improvements of the sort mentioned by Mr. North at the end of his paper.

The River and Harbor bill, approved July 13th, 1892, provides "That no preliminary examination, survey, project or estimate for new works other than those designated in this act shall be made." This proviso effectually bars the way against "the administrative officers of our Government proposing improvements, which by their capacity and convenience will cheapen transportation over large areas and develop increased production," until they are invited by Congress to present such a proposition. When a report covering this ground shall be desired by Congress, there will be no lack of ability to prepare it on a thoroughly comprehensive scale. Our country is large. A comprehensive scheme of the sort mentioned must cover a large area. It will be vastly expensive and it will require many years to carry it into effect. In fact its cost will be so great as probably to insure its rejection before time shall have been taken to consider that a large sum divided by many years means comparatively small annual expense. Congress moves slowly, as a rule, but the past season shows that it can take prompt action when public opinion makes itself sufficiently felt. The first step, then, is to awaken the public to a realization of its position, the rest will follow.

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657.

(Vol. XXX.—December, 1893.)

SUBAQUEOUS ROCK EXCAVATION.—DISCUSSION ON PAPER No. 606.*

By O. M. POE and JAMES DEAS.

O. M. POE, M. Am. Soc. C. E.†—The description by Mr. Deas of the method adopted by Colonel Beaumont for subaqueous rock excavation on the Clyde in 1880 (*Transactions* American Society of Civil Engineers, Vol. XXIX, page 138) is interesting, and the information is valuable. A large amount of that kind of work has been done under my direction during the last ten years, and I am an ardent advocate of subaqueous blasting and the use of dredges for removing the broken rock, in preference to the old method by means of a coffer-dam.

In August, 1883, I was assigned to the charge of the work of improving Detroit River, at the Lime Kiln Crossing, and of the Hay Lake Channel, in St. Marys River, Michigan. I found subaqueous blasting in progress upon both works. At the former, the contractor, Mr. C. F. Dunbar, of Buffalo, N. Y., had in use an efficient plant of his own. At the latter, the plant belonged to the United States, but it was

* "History of the Conversion of the River Clyde into a Navigable Water-Way, and of the Progress of Glasgow Harbor from its Commencement to the Present Day." By James Deas, C. E., Engineer Clyde Navigation. *Transactions*, Vol. XXIX, page 128.

† Colonel, Corps of Engrs., Bvt. Br.-Gen., U. S. A.

much less efficient that Mr. Dunbar's, although the idea was borrowed from his.

The history of the adoption of this method of subaqueous blasting by Mr. Dunbar, may be briefly given :

In 1866 or 1867, Mr. Dunbar had undertaken the removal of rock from the channel at the harbor of Erie, Pa., on Lake Erie. He drilled and blasted a portion of the rock through the ice, in the winter time, and, when there was no ice, used a raft for the purpose. All the drilling was done by hand. The average depth of the excavation in the rock was about 6 ft.

In the fall of 1872, Mr. Dunbar, as subcontractor to Mr. George Neilson, of Belleville, Ont., a contractor under the Canadian Government, undertook the excavation of subaqueous rock at the harbor of Port Colborne, Lake Erie. An attempt to drill the rock by hand failed, because the rock was found to be so hard that three men could only drill about 1 ft. in a day, and the use of some more economical method was imperative. During the winter of 1872–73, Mr. Dunbar constructed a steam drilling machine, using the hull of an old dredge to carry the machinery. He fitted the scow with a vertical spud at each corner to "pin" it up and hold it firmly in position, and laid a track on the edge of the deck along which to move the drills. On this track were mounted two 5-in. steam cylinder percussion drills, arranged to slide up and down in a vertical frame overhanging the side of the scow. The drills were raised or lowered by means of a windlass operated by hand, and were moved along the track by means of crowbars. The scow was 50 ft. long, and by starting one drill at the end, and the other at the middle of the track, each drilling five holes, at intervals of 5 ft. he was enabled to drill ten holes at one position of the scow. Holes 9 ft. deep could be drilled without changing the drill bits for longer ones. As soon as a hole was drilled to the requisite depth, it was charged and blasted without moving the scow. When one row of holes had thus been disposed of, the scow was moved back from the face of the excavation a distance of 6 ft., and the operation was repeated. The depth of channel made was 14 ft., which required the removal of the rock to an average depth of 2 ft., the maximum depth being about 6 ft. The rock was a hard, black, flinty limestone which could not be broken by charges of ordinary blasting powder, but yielded to more powerful explosives.

The work proceeded successfully from June to October, 1873, when the work was stopped. In 1875 the Canadian Government re-let the work, but required a channel depth of 17 ft. The contract was awarded to Mr. Dunbar, who used the machine described above, and successfully completed the undertaking. The difficulties encountered were : 1st, the extreme hardness of the rock (Mr. Dunbar considers it the hardest he has ever excavated), and 2d, exposure to heavy seas, which required the use of a machine that could be readily and quickly moved to a place of shelter.

During the progress of work under this contract Mr. Dunbar devised his apparatus for charging the drill holes. It is equally ingenious and simple, consisting of a copper cylinder having a smaller diameter than the drill hole, and length sufficient to admit the entire cartridge. At its upper end it is attached to a piece of iron gas pipe long enough to extend well above the surface of the water. The copper cylinder is slotted on one side throughout its whole length, to permit the insertion of the cartridge with its exploding wires fastened to the upper end. When the cartridge, with its wires, has been passed into the cylinder, the latter is inserted in the drill hole, and a long pole is passed down through the gas pipe forming the extension of the cylinder. The whole pipe is then withdrawn, the pole being used to prevent the cartridge from coming with the cylinder. As soon as the charging apparatus has been entirely removed, the cartridge is exploded.

So far as I am informed, this was the first steam drilling plant used in this manner for subaqueous work. It was afterwards greatly improved in some of its details, but the essential portions have not been changed. Among the most important improvements have been the introduction (while engaged upon the Lime Kiln Crossing work in 1879) of a hydraulic ram, to move the drills, both vertically and horizontally, and the use of a steam pump to force water into the drill holes for the purpose of cleaning them of all débris.

The latter device was first applied at Middle Neebish, Hay Lake Channel, where the excavation was in a very coarse, hard sandstone rock. The continuous use of the water-jet during the operations of drilling obviated the difficulty resulting from the packing of sand (drill cuttings) around the drill bit, which was often sufficient to render it impossible to withdraw the bit from the drill hole. It also left the finished hole entirely free from sand or other material which

would otherwise prevent the cartridge from going to the bottom of the hole. Simple as this device is, it made the difference between complete success and partial failure of the method at this locality.

While Mr. Dunbar was employed upon the contract of 1875, Mr. W. G. Thompson was resident engineer of the Welland Canal, including the harbor of Port Colborne, and Mr. C. James was the assistant engineer in charge. If these gentlemen are still living, they will doubtless remember all the facts concerning the use of Mr. Dunbar's method for subaqueous blasting at Port Colborne Harbor.

Apparently Colonel Beaumont's adoption of a like method upon the Clyde in 1880 was entirely independent of any knowledge of what had already been done on Lake Erie in 1873, and again in 1875, as well as at Lime Kiln Crossing in 1879. If this be the fact, it must still be admitted that the credit of priority in the use of the method is due to Mr. C. F. Dunbar.

It may not be amiss to mention the prices paid for subaqueous rock excavation in recent years in this locality.

The last contract at Lime Kiln Crossing was taken by Dunbar & Sullivan, at $4.43 per cubic yard, measured in the bank. The material is a compact buff limestone. The excavation was made in a current averaging about 3 miles per hour, but frequently running with much greater velocity. The channel was narrow (only 300 ft. wide when the contract was signed), and used by a commerce averaging fully one hundred vessels per day, many of large size, which greatly interfered with the progress of the work and constantly endangered the contractor's plant, a fact which had its influence upon the price.

The last contract at Middle Neebish, Hay Lake Channel, was taken by John Hickler & Son, at $1.20 per cubic yard, measured in the bank, a condition being that the major portion of the material should be formed into a dike rising 4 ft. above the surface of the water. John Hickler & Son employed Dunbar & Sullivan to do the work, and, it is supposed, at a price sufficiently below that named in the contract to leave a margin of profit to the original contractors.

Dunbar & Sullivan are now at work upon two contracts for deepening the prism of St. Marys Falls Canal, one at $1.53, and the other at $1.47 per cubic yard, measured *in situ*. The material is Potsdam sandstone in strata of varying thickness. The depth of channel is 25 ft., and the average depth of cutting something in excess of 8 ft. The

canal is the highway for a commerce which last year amounted to more than 11 214 000 tons in 233 days. This passing commerce seriously impedes the work, but not to greater extent than was anticipated.

John Hickler has undertaken to excavate a channel 21 ft. deep, at Sailors Encampment, St. Marys River, through blue limestone containing a considerable portion of flint, the contract price being $2.43 per cubic yard, measured *in situ*, the average depth of cutting being something more than 6 ft. Subaqueous drilling and blasting have been in progress during the past season.

The prices noted indicate the economy of the method under discussion. It should be stated, however, that a coffer-dam at Lime Kiln Crossing would not have been practicable without such an interference with navigation as to be inadmissible, and at St. Marys Falls Canal the use of a dam would have been confined to the season of closed navigation, say, from December 1st to April 15th. Each winter's operations would have involved the construction of a new dam.

James Deas, C. E.—I have read Colonel Poe's remarks with much interest, and they are so full and explicit that they leave me nothing to say except that I was quite unaware until now, and I believe Colonel Beaumont was also ignorant of the fact at the time he undertook our work, that the mode of boring adopted by him at Elderslie Rock had been previously in use anywhere else.

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658.

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IMPROVEMENT OF RIVERS.—DISCUSSION ON PAPER No. 607.*

By TH. REHBOCK, C. O. GLEIM, WM. MURRAY BLACK and W. R. HUTTON.

Mr. TH. REHBOCK (translation).—Mr. Franzius asked me to give a short abstract of his paper. I only regret that I have not enough knowledge of English to speak in that language. I will limit myself to give in a few words a general geographical description of the river, of the purpose, means and results obtained, up to the present moment, by the executed works.

The River Weser is considered abroad as a large river with considerable discharge, while, in fact, its lower maritime part only is of any consideration, so far as the volume of water is concerned.

The River Weser is formed by the union of the rivers Fulda and Werra at Münden, 227 miles above Bremen. This part of the river, called the Upper Weser, has a drainage area of 15 400 sq. miles, and an average descent from 1 : 2 000 to 1 : 6 000. The Upper Weser, although navigable over its whole length, is up to this date of no importance for traffic, because there is no navigable connection with the

* "Description of the Lower Weser and its Improvement." By L. Franzius, Ober-Bau-Director, at Bremen, Germany. *Transactions*, Vol. XXIX, page 173.

other German water-ways, and its depth is insufficient during dry seasons. Nevertheless, it is to be expected that at no very distant future, in connection with the execution of the Rhine, Weser and Elbe Canal, the Weser, from Bremen to Münden, will be transformed by canalization into a first-class inland water-way, which will connect the flourishing trade of Bremen with the Rhine and the Elbe.

The tidal course of the river begins at Bremen, and bears between this town and Bremerhaven the name of Lower Weser. The improvement of this part of the river is described in the paper before you. The Lower Weser has a length of about 40 miles. It receives from the Upper Weser a quantity of water, varying from 2 500 to 140 000 cu. ft. (70 to 4 000 cu. m.) per second, while the lowest part near Bremerhaven is subjected to a mean tidal rise of 10 ft. 4 in. (3.30 m.), corresponding to a volume of water of 230 000 cu. ft. (6 400 cu. m.) per second.

In former centuries sea-going vessels of small draught could navigate the Lower Weser up to Bremen, which town by this fact became one of the richest commercial places in Germany. In the beginning of this century, however, the bed of the river was in such a bad condition that no sea-going vessel could reach Bremen, and their cargoes had to be discharged into lighters at Vegesack or Brake.

While Bremerhaven, founded in 1830, with a sheltered roadstead and large dock-basins, satisfied the requirements of the transatlantic trade, the traffic to the town of Bremen was hindered so much by the bad state of navigation on the Weser, that in 1887 the State of Bremen decided to spend 30 000 000 marks ($7 000 000) in carrying out the project for the improvement of the Lower Weser, presented by Mr. Franzius, in order to gain a good access from the open sea for the new harbor of Bremen, constructed from 1885–1887, at a cost of about an equal amount.

The programme of the improvement of the Lower Weser is the creation of a uniform channel of 6 m. (nearly 20 ft.) in depth in the entire upper tide basin above Bremerhaven, and the maintenance of the conditions thus created by the power of the increased and regulated current, with little other assistance.

The means to accomplish this object is the formation of a regular river-bed, gradually narrowing up stream, guided by training-walls, which enclose the low-water section, and the execution of large dredging operations in order to attain the necessary depth.

At the beginning of this year more than 17 miles of training-walls and of closing walls were finished, and 600 000 000 cu. ft. (17 000 000 cu. m.) of soil had been dredged. The expenses up to this time amount to 24 000 000 marks (nearly $6 000 000). The propagation of the tidal wave is already so much facilitated, that the tidal range has been increased 2 ft. (60 cm.) at the Great Weser bridge at Bremen, and the flow of the tide lasts one hour longer than formerly.

The depth of water in the channel up to Bremen, which in 1886 was only 9 ft. (2.75 m.), is in this summer more than 16½ ft. (5.0 m.) at ordinary tide, enabling vessels like the North German Lloyd steamer Hanover, with 2 571 register tons, to come up to the harbor of Bremen.

The part of the estuary of the Weser from Bremerhaven to the open sea, 35 miles long, called the Outer Weser, has no well-defined banks, and bears the character of a gulf, being from 1.2 to 12 miles in width.

The depth of this part is at high-water time sufficient for the largest vessels, while at low water the navigation is hindered by a bar, five miles from Bremerhaven.

In order to remove this bar, which is the result of a split in the river, and to establish a fixed channel, the governments of Prussia, Oldenburg and Bremen adopted a project of Mr. Franzius and appropriated 3 000 000 marks ($700 000) for its execution. In 1892 a training-wall about 4 miles in length was built, reducing the width of the river more than half a mile, with the result of increasing the depth of the river more than 8 ft. (2.50 m.).

The project, the execution and the results attained in the improvement of the Lower Weser will be published, with all technical details, in the course of the next year.

C. O. Gleim, Cor. M. Am. Soc. C. E. (translating some remarks made in German by Mr. Rehbock).—Mr. Rehbock wishes to ask a question; that is, whether any apparatus for stirring the soil, in order to deepen the channel, has been employed in the United States? That is occupying their attention in Bremen at present, and he would like to get some information. Mr. Rehbock has just given the information in regard to the requirements on the lower part of the Weser. They have now a call for competitive plans—an international competition—for plans proposing an apparatus to stir the soil, so that, with the strong current they have with the tide, the sand would be washed out without dredging. He says no such apparatus has been used on the Continent, except at Dunkirk, which has not been successful.

WILLIAM M. BLACK, M. Am. Soc. C. E.—The only case I know of that kind has been the stirring up of the bottom by strong jets of water; this has been done with more or less success. In the case of the stirring up by dynamite, it was found that the material was started up very successfully, but the sand was deposited very soon and very close to the point from which it had been started.

Mr. REHBOCK (translated by Mr. Gleim).—The cases referred to by Captain Black are rivers where it is really an estuary near the sea. In the case referred to, on the Weser, they have a great deal of silt, and it is the silt that they wish to have stirred up and carried out, and not the sand. The bar is effected by the training wall that they have erected on the other side.

Captain BLACK.—There was a method of deepening bars in use on some of our western rivers some years ago by scraping. What was known as "the Long scraper" was made by fastening a semi-cylinder of heavy metal at the end of a handle, forming a tool in appearance much like the dipper of a dipper-dredge. This was attached to the stern of a scow and drawn across the bar. It was used successfully for a good many years, but the improvement made by it was found not to be permanent.

Another method used on the lower Mississippi now, just after the flood has passed and before the low-water channel has been formed, to cut through a temporary bar, is to drive piles directly along the middle line of the proposed channel, in a row, about 10 ft. apart. It is found that these induce sufficient scour to open the channel.

Another method has been tried on the ocean bars in the South. Charges of dynamite are sunk a few feet below the bottom, over the bar. These are exploded, and the sand thrown up by them is carried away, to a greater or less extent, by the tidal currents. The difficulty with all of these devices arises from the fact that the sand and heavy sediment are deposited within a short distance of the point from which they started.

On the Willamette River, bars have been cut through by propeller dredging. This is done by mooring a deep-draught steamer above the bar, with stern down stream. When the propellers are started ahead very rapidly, a channel is cut through very quickly by the strong currents produced. The same method of dredging I have seen used successfully in sand, where it was desired to obtain a deepening that was

* Capt., Corps of Engs., U. S. A.

only local. In all these cases, however, the sand is deposited a short distance from the place whence it started. I have seen that in hydraulic suction dredges. In using a dredge of this description in shoal water I have seen the sand deposited 10 ft. from the extremity of the outflow pipe. The deposit was made so locally and rapidly that it threw up a bank along the edge of the cut, showing how quickly the sand, raised up and moved in this manner, is deposited.

W. R. HUTTON, M. Am. Soc. C. E.—This paper is not a criticism of the work done upon the Weser. That is a successful work and therefore beyond criticism. It had for its object to make a navigable channel of a given width and depth from Bremen to the sea. The methods adopted procured a sufficient measure of success and, doubtless, at the smallest cost. This is true engineering; the proper and judicious application of the means to obtain a given result.

But to the writer it seems that some of the methods employed, judicious under the circumstances, have not the special merit attributed to them, and may lead the young engineer into trouble if unintelligently followed.

The method of improving tidal rivers was first analyzed and described by Mr. Caland, in preparation for the design of the Rotterdam water-way. He treats the entire river channel as an elongated estuary, arranged to cause the flood tide to ascend as far as possible from the sea and with the greatest possible range of tide, thus introducing the largest quantity of tidal water into the river-bed. For this purpose there is required a depth nearly uniform, and a width diminishing regularly from the mouth to the head of tide, in proportion to the diminished quantity of water passing through each succeeding section.

The paper under discussion appears to be a revision after another year's experience of one presented last year to the Paris Congress of Inland Navigation. The discussion upon that paper was confined almost entirely to the question whether the regulated channel should be formed and maintained by dredging or by scour, the Rotterdam water-way being cited in favor of the exclusive use of dredging as against the practice on the Weser, where a large quantity of material was moved by scour. The cases are not comparable. The most appropriate method was adopted at each place.

In the paper of last year it is recommended that all the secondary

channels or large arms of the river which are to be closed should be left open at their lower ends, that they may be filled by the flood tide, and thus contribute to augment the volume of water circulating through, the estuary, both at flood and ebb. This recommendation is not repeated in the paper of the present year, but is referred to here because it seems to have been approved by high authority in the Paris Congress, although not in conformity with the accepted Caland theory. That theory excludes all irregularities of width, everything which may diminish the volume of the ascending tide.

The cross-section of the New Weser consists of two parts, a deep central portion or low-water channel, in designing which Mr. Franzius has followed what we may call the Caland method, and shallow lateral parts, the bottoms of which are about at the level of low tide. The flood tide-wave passes up the deep central channel with a velocity proportioned to its depth.* The lateral beds being very shallow, their velocity will be insignificant, and during flood tide they will be "filled from the middle section and will empty themselves back into it during ebb tide, thus operating like elongated flushing basins" or lateral reservoirs.

This arrangement is exceedingly defective as a means of increasing the tidal power and range, and obtaining the highest results in the improvement of the river-beds.

The volume of the flood wave is diminished by the water abstracted to fill the lateral beds, its height and velocity are reduced and its *vis viva* lessened, to the injury of the whole river-bed above. Less water ascends to the head of the tide and less flows out with the ebb.

This feature, however, found no objection in the committee of the Paris Congress, and seems to have been in the mind of the engineer of the Seine when persistently defending the use of lateral reservoirs in the bed of the stream.

The effects of the side beds would be similar to that of the lateral reservoirs condemned by the committee, except that, being continuous, their consequences are not abrupt, but gradual, and therefore not perceptible.

* Green's formula referred to in the paper is $v = \sqrt{gt}$, t being the depth of the center of gravity of the section below water surface. The formula used by the engineers of the Seine is found to agree fairly well with observation, $v = \sqrt{g\,(H + h)} - U$, where v = velocity of tidal wave, H = depth of low water, h = height of wave, U = velocity of ebb current.

The real merit of the plan, as applied to the Weser, consists in the very large saving in cost, combined with a sufficient improvement of the navigable channel, rather than its efficiency in improving the navigability of the river.

Mr. Franzius has explained the method of determining the high-water and the low-water channels in other publications, not now accessible. In his judgment they should co-operate to increase the volume and the velocity of the water in the river.

The fact is not overlooked that the Clyde and other rivers of Great Britain and elsewhere have been improved to the highest degree by the use of low or half-tide training walls. In them, as a general rule, are present the conditions which justify the use of the low dyke, viz., the lateral beds or reservoirs are so near the mouth, and the mouth so large, that, 1st, the volume of water passing into the river above the reservoir is not diminished by the filling of the reservoir; 2d, the emptying of the reservoir into the sea does not obstruct the outflow of river water from above.*

* Amélioration de l'Escaut. Vème Congrès International de Navigation Intérieure.

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659.

(Vol. XXX.—December, 1893.)

HARBOR IMPROVEMENT.—DISCUSSION ON PAPER No. 608.*

By JOHN PURSER GRIFFITH.

Mr. JOHN PURSER GRIFFITH.†—There are in the British Islands many piers and breakwaters constructed on the same principles as those described in this paper on Leixões harbor, and I have been asked to give in a few words my experience of these structures. One of the most important examples with which I am acquainted is Holyhead breakwater. It is constructed in deep water and in an exposed situation. The masonry superstructure or backbone is founded on the rubble mound about low-water level, and is protected on the sea side by a great foreshore of large rubble stones, originally rising to high-water level. Twenty years of exposure to the storms of the Irish Sea has reduced the rubble foreshore to little more than a pebble beach, flattening down the foreshore and threatening the denudation of the rubble masonry foundations. The destructive action of

* "A Brief Account of the Building of Leixões Harbor." By Alfonso Joaquim Nogueira Soares, Inspecting Engineer in Charge. *Transactions*, Vol. XXIX, page 194.

† Of Dublin, Ireland.

the waves is increased by the vertical wall, the waves being increased in height and reflected on to the foreshore. The rubble is rolled about and transferred from one part of the breakwater to another, forming local accumulations, and sometimes entirely removed from that part of the work where it is most required. In the great piers which enclose the harbor of Dublin we have had some rather striking experiences of the effect of waves on rubble mounds. Poolbeg Lighthouse, the principal light of Dublin harbor, is at the extreme seaward end of the Great South Wall, which extends 3¼ miles into Dublin Bay. The base of the tower was formerly protected by a foreshore of rubble. Each winter's storms removed some of this, making it travel in the form of a stone wave landwards along the pier. Season after season this stone was brought back to the base of the lighthouse tower or replaced by fresh stone, the annual cost of so doing amounting to about £800. Some twenty-five years ago, concrete blocks, weighing 40 tons each, were built *in situ* on the foreshore in the expectation that as the foreshore was washed away the blocks would settle down and stop further denudation. Some of these blocks were actually carried away by the sea from the place in which they were built, and it was found necessary to gird the exposed side of the lighthouse with concrete blocks, each weighing 140 tons. These have succeeded admirably, and for years all expenditure in protecting the base of the lighthouse has practically ceased, and the blocks are now as perfect as the day they were laid.

On the north side of the harbor entrance there is a breakwater entirely composed of rubble stone. The outer end of this pier for several thousands of feet in length is a half-tide level wall, over which very heavy seas break, and yet the mound has practically remained stable for seventy years. These two examples seem to point out that a rubble mound surmounted by a vertical superstructure is in a condition of much less stable equilibrium than if the superstructure were omitted and the sea allowed to break over the pier.

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660.

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IMPROVEMENT OF RIVERS.—DISCUSSION ON PAPER No. 609.*

By H. ENGELS, WM. MURRAY BLACK, W. R. KING and JOHN PURSER GRIFFITH.

Prof. H. ENGELS.—In presenting my paper to the Engineering Congress, I beg to add a few remarks to prevent a misunderstanding in regard to No. 1 of the conclusions contained in the paper. I do not wish to be understood as saying that rivers still undergoing the process of erosion are incapable of regulation. Such rivers I have declared adapted to canalization. But every canalization must be preceded by regulation. What I wished to emphasize is this, that in rivers of that class the attainable limits of navigability cannot be produced by regulation, nor permanent success gained by means of regulation. Improvements may certainly be effected by regulation in a river yet in the state of erosion; but, the river itself not having attained a permanent condition, the improvement of its condition effected by regulation

* "The Limits Attainable in Improving the Navigability of Rivers by Means of Regulation." By H. Engels, Professor of Hydraulics, Royal Technical High School, Dresden, Germany. *Transactions*, Vol. XXIX, page 202.

cannot be expected to be permanent. For this reason it is impossible in rivers of this kind to determine in advance the limits of navigability attainable by regulation.

WILLIAM MURRAY BLACK, M. Am. Soc. C. E.*—We may well believe from the evidence given by the structures on land that statical engineering is rapidly becoming an exact science. Where an engineer has to deal with the forces of Nature exerted through the winds, waves and currents, he is made to feel that as yet the accumulated knowledge of the world gives him very little exact data to guide him; the formulas are largely empirical, and this branch of engineering science is still in the experimental stage.

As emphasized by Mr. Engels, in all hydraulic work experience and common sense are most important factors in securing successful results. Each particular problem requires its own study, and an engineer cannot treat a river successfully without such study any more than a physician can cure an obscure disease without an intimate knowledge of the patient's characteristics.

The causes of the obstructions in a river's bed and the motion and fluctuations of the water in that bed must be determined carefully before it is possible to determine the extent to which the obstructions can be removed and the width and depth of channel which can be obtained and maintained. It is easily possible to destroy good existing navigable conditions in the upper reaches of a river by misdirected and ill-considered work below. The entire stream and its capacity for commercial uses should be considered together.

This paper is a timely and admirable discussion of this very important subject.

Mr. Engels notes the surface elevation of a stream along the concave shore of a bend. An example of this was given to me a short time ago by General Comstock, President of the Mississippi River Commission.

In a bend of the Mississippi River with a radius of one mile at a point where the river is 3 000 ft. wide, the centrifugal force may cause a difference of head of about 2 ins. on the two sides, higher on the concave. Along this concave bank the velocity is greater and the centrifugal force higher at the surface than near the bottom. The head of 2 ins. before mentioned then causes a downflow along the concave bank, pushing the lower strata of water out. Thus, a current is started

*Capt., Corps of Engrs. U. S. A.

toward the convex bank, carrying with it the eroded materials and piling them below the convex point.

Another phenomenon seen on the Mississippi River and perhaps observed on streams carrying a less volume of sediment is this. On the lower Mississippi, which carries a large volume of sediment, it is well known that a rise of surface is frequently followed by a rise of the level of the bottom, so that the increase of surface height by no means necessarily indicates an equal increase of depth. The thalweg of the Mississippi River at low water is a channel winding through the greatly broader thalweg of the stream at its high stages. The great increase of energy accompanying a rapid rise of the river is first expended in straightening the low-water thalweg. Flood water from the Ohio or Missouri rivers enters the Mississippi laden with sediment, and the total volume of sediment of the river is at once increased by the sediment eroded in straightening the low-water thalweg. As the water rises the low-water banks are overflowed, and the broader valley is filled. After the crest of the flood wave has passed, the current velocity is decreased and a portion of the sediment is deposited. The falling water then becomes more shoal in the wider thalweg of the high river, and the minor features of the bottom which, during the flood, had had but little effect on the surface and slope, begin to be noticeable. The velocity ceases to be uniform through long stretches. Erosion of the bed begins where the velocity is greatest, and as the channel there is deepened, this increase of velocity, accompanied by erosion, is transmitted up stream until the river has again excavated its low-water channel. I think this may be considered a fair statement of what takes place after a flood, and any one familiar with it knows that the channels of the Mississippi River are almost always changed after the flood and before the low-water channel becomes re-established.

I would very much like to have Colonel King give his experience on the Tennessee River, because that is a case not covered by Mr. Engels' paper, although it is a case which comes under the principles of that paper.

Colonel W. R. KING.*—As I left that work some seven years ago, and have hardly thought of it since, my thoughts on the subject are a little scattered, and will not be as clear as they ought to be. It was only this morning that I received the first intimation that this paper would come up, or that I would be likely to have anything to say about it.

* Col., Corps of Engrs. U. S. A.

The Tennessee River is an exception, I might say, to all rules that are usually laid down for the improvement of rivers, and in getting the available depth the conditions are entirely different from any that are mentioned in Professor Engels' paper. The Tennessee is not a shifting stream; it is a "completed" stream, and the regimen is almost constant. In certain places there is a little washing, but generally the bed and banks, of rock and gravel, are not disturbed very much either by floods or by low water. To find the greatest depth that can be attained at reasonable expense, we proceed somewhat tentatively. At the shoal places the river has generally spread out, perhaps one mile wide, though its normal width is only about 1 000 ft., and we simply cut a channel of suitable width through the obstructions, at the same time narrowing the channel by wing dams, or by closing side channels, so as to keep the deepened channel filled to the required depth. If we should cut out the channel and make no contraction in the river, we would have a channel without water enough to fill it, and would lower the pool above so as to cause secondary obstructions to appear. We, therefore, attempt to contract the channel in width as much as we enlarge it in depth, and this can generally be done without applying formulas; we find in that way that we can improve the worst obstructions without producing obstructions elsewhere.

As to the greatest depth that can be gotten, we must have a certain width, and, knowing that and the low-water discharge of the river at that point, we can find out the depth of channel that we can effect.

Then we have another thing to look after—the rapid current. And to avoid this, the wing dams must be properly located, so as to back the water up to the obstruction without raising it much on the crest of the reef. If we undertake to get too great an increase in depth, the number of obstructions to be removed, as well as the cost of overcoming each separate obstruction, will increase very rapidly. In a river like the Tennessee, where the demands of navigation are limited, we find that if we attempt more than about 3 ft. it would involve too many obstructions. We have worked in that way, trying to improve the worst obstructions. The boats can take advantage of the higher stages of the water, and are not compelled by the necessities of commerce to use the extreme low stages. We have balanced the matter of cost and depth in that way, finding that it would not cost excessively to get, say, 3 ft., but that to get another foot would bring in too many secondary obstructions, and greatly increase the cost.

Again where, as at Muscle Shoals, we were obliged to resort to locks, we built the locks in such a way that boats of greater draft than can navigate the river at low water can pass them, because the locks can be used at high water; we found 5 ft. on the miter-sill was an economical depth, and would give ample accommodation to the commerce of the river. As the entire length of navigable water on the Tennessee and its tributaries is about 1 000 miles, the cost of radical improvement by lock and dams would be too great to be thought of, considering the extent of commerce involved.

Instead of being of a temporary nature, this work, as executed, is comparatively permanent, from the fact that we have a good foundation to build on. The dams are sometimes built of small stones. We found, if built up like ordinary walls, even if large stones were used, they would be torn out by one flood; but by laying the stones lapping on each other like shingles, they would remain.

The cost of this kind of improvement per mile is but a small fraction, say, 10%, of what is often spent on smaller streams in Europe.

There is a whole class of streams, like the Tennessee, where the conditions are entirely different from the conditions assumed in Mr. Engels' paper, and these remarks are mainly intended to prevent a hasty conclusion that because the Germans and French are unable to make certain permanent improvements on their rivers, we cannot do it with ours.

Mr. John Purser Griffith.*—When I first looked at Professor Engels' paper I must admit feeling rather like one of those described on page 221 of his paper, "who, on account of the title, have counted on an exposition equipped with great mathematical and speculative apparatus, who have expected that the question propounded would be solved in an abstract, theoretical manner." Such, Professor Engels predicts, "will be disappointed." I was disappointed, but very agreeably disappointed.

I found that the paper was not merely a discussion of the problem from a theoretical point of view, but was full of the results of the keen observation and sound judgment of a practical engineer. I have read the paper with great profit, and specially note the important distinction drawn between the "finished" and "unfinished" reaches of rivers and their importance where regulation works have to be con-

*Of Dublin, Ireland.

structed. The paper is full of matter worthy of close study, and in one particular seems to be unique, for I cannot recall having met with the influence of ground or spring water so fully discussed elsewhere.

Another point of great interest has been raised, namely, the use of models in solving certain problems connected with the flow of rivers and the transport of sand and silt. My friend the late Professor James Thomson, of Glasgow University, was, I believe, the first to investigate the problems connected with the flow of water round river bends by means of models. He also proved the existence of vertical upward and downward currents in rivers produced by the retarding influence of the bed of the stream, and showed that these currents accounted for the surface velocity not being the maximum velocity.

I simply refer to these experiments of Professor Thomson that Mr. Engels may be encouraged in his researches by the aid of models. Those interested in the subject will find Professor Thompson's experiments fully described by himself in the reports of the British Association.

Prof. H. ENGELS.—In reply to Colonel King, I have to say that my remarks—as I ought to have mentioned—refer to rivers with unstable beds. In the case of a river with a rocky, stable bed, and to this class, according to Colonel King, the Tennessee seems to belong, a depth can certainly be obtained depending only on the following elements: 1, available funds; 2, quantity of water at low stages; 3, admissible minimum width of channel; 4, admissible maximum rapidity of current; the last two conditions being governed by considerations of navigation.

As to the case of the Muscle Shoals, it does not seem to form part of the subject under discussion, being a case of canalization and not regulation.

Neither is the conclusion at which Colonel King arrives founded on the contents of my paper. Nowhere did I say that the Germans and French were unable to put their rivers in a good permanent condition by means of regulation. I only explained that this was impossible in the case of "unfinished" rivers; and this is equally impossible with American streams in case the latter are unfinished.

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661.

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IMPROVEMENT OF HARBORS.—DISCUSSION ON PAPER No. 610.*

By JOHN PURSER GRIFFITH, WILLIAM MURRAY BLACK, WILLIAM P. CRAIGHILL and THOMAS W. SYMONS.

Mr. JOHN PURSER GRIFFITH.†—I wish to express the pleasure with which I have listened to Captain Black's paper. It opens up a subject of such importance to all nations that I think it finds a fitting place in this International Congress of Engineers, although, of course, our discussion must necessarily be of a very limited character. I think we shall all agree that in many respects the instances quoted by Captain Black of the improvement of harbors on the South Atlantic coast of the United States differ in many important features from the best-known cases of harbor improvement on our British coasts. The absence of tidal and littoral currents is in itself a distinctive feature of the harbors to which Captain Black refers. In many of our British ports these form such an important factor that they cannot be disregarded. In the case of the port of Dublin, with which I have been

* "The Improvement of Harbors on the South Atlantic Coast of the United States." By William Murray Black, Captain, Corps of Engineers, U. S. A., M. Am. Soc. C. E. *Transactions*, Vol. XXIX, page 223.

† Of Dublin, Ireland.

associated for the last twenty years, the keynote of the success which has attended the efforts made to improve the bar has been due to a full appreciation of these littoral and tidal currents by the engineers who designed the works which led to the great increase in the depth of water on Dublin bar.

Dublin bar has been improved by artificial scour resulting from the construction of a tidal reservoir of 2 500 acres, enclosed by two great piers extending out over the strands of Dublin Bay. These piers have been so formed as to make the outward scouring current flow in unison with, and not in opposition to, the littoral currents in the bay. Before beginning the works which have proved so successful, both time and money were spent in fully investigating the problem. I have fully described these works in a paper read before the Institution of Civil Engineers in 1879, which is published in their Proceedings, and it is therefore unnecessary for me to enter now into greater details than to say that they have resulted in increased depth on the bar of 9 ft. 6 ins.

I most cordially agree with Captain Black in a point to which he refers more than once, namely, the injurious effect of "meager and intermittent supply of money for carrying works into execution." In marine works this seems to be specially the case. The sea seems almost to take a delight in thwarting a timorous or vacillating policy. I could name numerous works which have suffered from this. The lay mind of the Parliamentary representative, who has to vote the funds for such works, readily falls in with the argument that it is better to make a comparatively small annual grant instead of voting the full estimated cost, on the ground that they will see how the work succeeds before voting away large sums of money, the result often being that extraneous influences are brought to bear, votes are cut down, works are delayed and much of their utility lost by encroachment and damage to the unfinished work. In the case of piers run out on sandy shores, slow progress is often followed by rapid advancement of the low-water line.

The manner in which the works for the improvement of Dublin bar were carried out forms a striking exception to this hesitating policy. The Dublin Harbor Board, then known as the Ballast Board, acted very wisely in first obtaining the best professional advice, and thoroughly investigating the problem, and then obtaining the necessary

funds before proceeding with the work. By this means the works were allowed to proceed rapidly, and I believe this proved to be no small factor in their success. In fact, I believe the only way to deal with these problems is, to investigate the case thoroughly, to make up your mind thoroughly, and to proceed with the work rapidly. It is better to proceed thus than to endeavor to find the best possible design by a series of tentative stages.

The introduction of sand-pump dredgers in England seems to promise great assistance in dealing with ports on sandy coasts. A very interesting experiment is at present being carried out on the Liverpool bar, where they have just got a sand-pump dredger designed to raise 3 000 tons per hour. As the result of two years' dredging with their smaller sand-pump dredgers I was able to cross the bar in the R. M. S. *Britannic* a few weeks since at one hour after low water, which was unique in the experience of the White Star Line. We are therefore watching the result of this great dredging experiment with much interest.

WILLIAM MURRAY BLACK, M. Am. Soc. C. E.—The method of conducting the improvement of rivers has been alluded to, and, I think, in justice to the branch of the service to which I belong and by which the greater part of the work has been done, it may be well to explain how it comes that the work of river improvement is so unsystematic as it is. The award of appropriations for the improvement of rivers and harbors lies in the hands of Congress. A number of years ago it was enacted that no improvements should be started until the necessity for them had been certified to by the Secretary of War.

The routine method is this: In the River and Harbor bill is inserted provisions like the following, taken from the act approved July 13th, 1892. * * * "The Secretary of War is hereby directed to cause preliminary examinations to be made at the following localities, to wit:" * * * (Here follows a list of the points to be examined.) * * * "That the preliminary examinations ordered in this Act shall be made by the local engineer in charge of the district, or an engineer detailed for this purpose; and such local or detailed engineer and the division engineer of the locality shall report to the Chief of Engineers, first, whether, in their opinion the harbor or river under examination is worthy of improvement by the General Government, and shall state in such report fully and particularly the facts and reasons on which they base such opinion, including the present and prospective demands of commerce; and, second, if worthy of im-

provement by the General Government, what it will cost to survey the same with the view to submitting plan and estimate for its improvement; and the Chief of Engineers shall submit to the Secretary of War the reports of the local and division engineers, with his views thereon and his opinion of the public necessity or convenience to be subserved by the proposed improvement; and all such reports of preliminary examinations, with such recommendations as he may see proper to make, shall be transmitted by the Secretary of War to the House of Representatives, and are hereby ordered to be printed when so made." Then follows the appropriation of a lump sum to cover the cost of the work so directed.

The money so appropriated is allotted to the various works, and the examinations are made and the reports submitted as required. The examinations and surveys are made as carefully and fully as the allotments will permit. The funds available are not always as great as the local engineers require for the best results. But insufficient appropriations seem unavoidable when the extent of our country and the great number of local demands for improvement are considered. Indeed it seems that we are not yet sufficiently wise to appreciate the absolute interdependence of the various portions of our country and to see that the prosperity of all is dependent on the prosperity of each. Each community, while seeing and urging the claims of its own locality, forgets or neglects the needs of others, and becomes indignant at the inadequate provision for its local improvements, while holding up its hands in horror and calling names on account of the large sums appropriated for such work in general. The pressure of public opinion compels Congress to provide for works of improvement at many points, while the same pressure prevents Congress from making the adequate appropriations which, as is fully known, the interests of commerce and of true economy both demand.

In preparing his project the local engineer considers to the best of his ability all of the factors involved. Important projects are then generally submitted to a board of engineers for further consideration, and finally they are considered by the committees of the two Houses of Congress. It is a grave mistake to assume that this final consideration by Congress is simply a log-rolling affair. The writer has appeared at times before the committee of each House, and has found the members, not only interested in the engineering points on which he was interrogated, but posted to an unlooked-for degree on the local peculiarities of the works of his district.

An instance of the injustice of the popular clamor about log-rolling in connection with the River and Harbor bills is given in the history of the Act of August 2d, 1882. This act was vetoed by President Arthur, after many accusations of log rolling and extravagance had been made by a portion of the public press. It was passed over the President's veto. At the following session, the House of Representatives called on the Secretary of War by resolution for a list of the appropriations made in the Bill for Improvements which he considered unworthy, with his opinions. When this list was given to the House it was found that the total amount of the appropriations objected to was only 5½% of the total amount appropriated in the bill and a subsequent investigation showed that the objections urged with regard to many of the objected-to items were based on a misconception of the facts.

Should Congress consider the work proper and the project judicious, it then starts the improvement by an appropriation. Here, again, the vast number of demands hampers it, and the appropriation necessarily is insufficient. In the case of a few of the more important works Congress has made provision for continuous work by special appropriations; but this, in the present state of public opinion, is manifestly impossible for the great number of works now being carried on, nor is it possible, for the same reason, to abandon any of the partly completed works.

The results of insufficient appropriations are twofold. The works cannot be carried on in an economical manner, nor can the work be done systematically. The same local demand which calls for the widely distributed appropriations calls for the immediate expenditure of the sum available, if only for the removal temporarily of the most annoying obstructions to navigation. Congress and the engineers are alike servants of the people and must do their will. That the projects are as well considered as human failings will permit, and that the engineers, executive and advisory, are free from local prejudice and are earnest in the discharge of their duties, will, I think, be admitted. The shortcomings of the system can usually be traced to the demands of the people, who pay for their work, and the remedy lies in that broader education which will admit the judgment of a wider knowledge and which will hold local interests subservient to the needs of the whole nation.

W. P. CRAIGHILL, M. Am. Soc. of C. E.*—The thoughtful reader of Captain Black's very valuable paper will find profit as well as interest in examining very carefully an article on sea beaches by Professor H. S. Shaler, of Harvard College, in which he treats that subject in detail and in a most instructive manner.

Captain Black is, I think, quite right in his supposition that the mouth of the Cape Fear River was at some time near Federal Point. It is even probable that the mouth in the more distant past was still nearer Wilmington. The existence and character of a peculiar obstruction called "the logs," formerly found a few miles below Wilmington, seem to prove it. This obstruction was called "the logs" because supposed to consist of sunken logs on the bottom which had floated down from above and been lodged there. When this impediment to navigation was attacked in the progress of the improvement of this river under my direction, no logs were found at all. It consisted of the stumps of a cypress forest which had evidently stood long years before. These stumps were found *in situ* in what was the main channel of the river at the time of their removal. Their tops were, many of them, nearly as smooth as if they had been sawn across, and all at about the same level of 9 ft. below mean low water. The machine used in the first removal of the stumps was a clam-shell dredge from which the bucket was removed and replaced by a grapnel. Generally the power of the engine was sufficient to pull the stumps, with attached roots, etc. In some cases it was necessary to depend on the slow but irresistible lifting action of the rising tide. The stumps were sound, and this condition might have come from their immersion in the mud which was even with their tops. But the trees had disappeared. How and why had they been cut off? It was supposed the land had at some time subsided so as to permit the income of the teredo which had eaten off the trees and then destroyed them completely after their fall into the water. But this theory required a rising again of this same portion of the soil, as the water there does not now contain the teredo or any insect destructive to timber.

The place called the "Haulover," where the New Inlet was opened in 1761, took its name from the habit of boatmen who hauled their craft over the lowest part of the low sand beach which separated the ocean from the river. The beach was gradually worn down at this point, and was in a condition to be more readily broken through when the gale came in 1761 to open the inlet.

* Col., Corps of Engs., U. S. A.

Since the closure of New Inlet, while the accumulation of sand on the actual line of the closure has been very small, the beach has grown and extended very much to the southwest from a point nearly opposite Fort Fisher, so as to form a large bay between it and the closure-dam. This bay will probably fill in time with sand which is thrown up on the spit by the waves, and then dried and blown by the wind into the bay.

The day will probably come when people seeing a wide expanse of sand between the ocean and the present dam will wonder why such a dam was built, as the need for it at any time will then not be apparent. And it is not unlikely the material from it may some day be safely removed and used at other points, as, for instance, in constructing one or more jetties at the mouth of the river, should it ever become necessary to greatly increase the depth now available there.

The space where General Butler's powder-boat was exploded off Fort Fisher, and where the fleet lay during its attack and capture on a subsequent occasion, is now filled with sand and is either dry at low water or nearly so. Zeke's Island has also grown very much since the building of the closure-dam.

The shape of the closure-dam from Federal Point to Zeke's Island has been criticized and inquiry made why it was not in a straight rather than a broken line. The reason for the peculiar shape is the following: When the dam was planned there was a long shoal extending in a southwest direction from Federal Point, and one then extending in a northwest direction from the upper end of Zeke's Island. The sections of the dam from Federal Point and Zeke's Island were placed on these shoals, because they were there and because the section next Federal Point would act as a deflector to the ebb current as it came down the river, throwing some of it at least into the main river and away from the inlet. The section of the dam next Zeke's Island was placed so as to have a similar action on the flood current.

Much scour took place because of insufficient funds to push the work as rapidly as it should have been. This was particularly the case when the work was about the height of low water and between that level and that of high water. The distance from the dam to the ocean by the way of New Inlet being much shorter than by the proper mouth of the river, the tide changed its level on the ocean side of the dam much more rapidly than on the river side. This produced a very

strong tidal current at the dam, which increased in velocity as the opening was lessened. After the dam had reached the level of low water, there was quite an overfall at times, which also produced scour.

From necessity, much of the dam was built of small rock procured from the Cape Fear, the cost of large rock from the north or the interior prohibiting its use to any great extent. The unfinished dam of these small rocks was more than once much degraded by easterly gales which brought in the waves from the ocean with great violence.

The dam was finally coped with large flat rock. Some of these coping-stones are still occasionally displaced by severe storms.

The use of the "log-mattress" was due to economical considerations. This mattress was constructed in a very simple way of the materials at hand. The pine trees on the creeks emptying into the river near by were cut down and their trunks rolled into the stream and formed into rafts. These rafts were loaded with as much of the brush of the same trees as they would carry. They were then towed into position and sunk by being loaded with stone thrown upon them from barges. The prolongation of the dam below Zeke's Island was founded, as Captain Black states, on more regular mattresses, one of the continuous mattresses being three-fifths of a mile long, and very successfully placed.

While the jetty constructed many years ago at Baldhead Point with the object of holding that headland was a complete success from that point of view, it is worthy of note that the depth of the Baldhead Channel began to increase at the same time the jetty was separated from the shore. The question arises whether a jetty in that position was not injurious to the channel. The spur jetties constructed many years ago on the Fort Caswell side of the Baldhead entrance were completely successful in protecting the walls of that fort, which were once seriously threatened by the ocean.

It is considered that the beneficial effect of the work of the pump-dredge Woodbury on the Baldhead Channel was much greater than merely the removal of the cubic yards taken into her bins. Much more material was loosened by her drags and carried by the ebb tide into the deep water beyond the bar. Her work on the bar was mainly in a straight channel on ranges, the object being to localize the action of the increasing current as New Inlet was being closed, and to facilitate the deepening within moderate horizontal limits rather than have it spread out over the whole bar.

Much value should be given to the opinion of Mr. Bacon, quoted by Captain Black, that he was "convinced" from his observations that "the foundation, placed on sand or mud, most secure from undermining by water, is of small rip-rap stone," for Mr. Bacon was a man of most excellent judgment and a close observer. But it is thought this statement is too general. It is true that certain experiments, made by Mr. Bacon by my direction, showed that the mattress could be safely dispensed with in certain parts of the dam below Zeke's Island where the soil was of a special character, but it must be borne in mind that the location of that part of the dam was comparatively sheltered from the action of waves or currents. It is believed the mattress foundation can seldom be dispensed with where the underlying mud is soft and deep, or the sand is exposed to erosion.

Captain Black characterizes the work on the Cape Fear as "successful," and he is right (for it is a success to procure 18 ft. at low water in a great river where 9 ft. had been the ruling depth), and it gives me great pleasure here to record my obligations to Mr. Bacon who was my co-worker on it for many years. To him more than to any other man is due the success of the work. When he died of the grip a few years ago, I lost a good and trusted friend, and the General Government a most valuable and faithful servant. An honest, true man went to his rest from unremitting labor fruitful in good results.

Captain Thomas W. Symons.*—I have read with great interest Captain Black's account of what is going on in the way of harbor construction on the South Atlantic Coast. Such a paper gives to us who are personally unfamiliar with this section a clear and succinct account of what is going on there, and how plans, methods and ideas differ from those developed on this western coast. On the South Atlantic, as well as on the Pacific, there seems to have been an elimination of certain methods, processes, and devices, and a gradual settling down to an adopted style of work, with which Captain Black appears to be satisfied.

From Captain Black's description, it is evident that the works at the mouth of the Cape Fear River, at Charleston, and at St. Johns, are so widely at variance with similar works on the Pacific Coast as to be a matter of mark. It is safe to say that no officer having experience with similar work on the Pacific Coast would be satisfied with the plans and methods adopted and pursued at these Atlantic Coast ports. Starting

*Capt., Corps of Engrs. U. S. A.

from the sheet piling work at Wilmington, Cal., and the low-tide crib work at Yaquina, the officers of the Corps of Engineers on the Pacific Coast have gone through all the stages, and have now arrived at the conclusion that the proper form of jetty construction for the improvement of bar harbors is a high-tide stone jetty on a thick brush mattress foundation, built from a pile tramway, as described by me in a recent paper on the jetty harbors of the Pacific Coast. This is very different from the thin log or brush mattresses with low-tide rubble mounds, all built from floating plant, as described by Captain Black.

The Pacific Coast or tramway system presents many marked advantages over the Atlantic Coast system. It furnishes a solid and substantial base on which mattresses of any desired thickness and width can be readily made at the site they are to occupy, and where they can be quickly sunk into place and held there by the piles and the stone placed upon them. All operations can be carried on continuously regardless of the tide, and almost regardless of storms. It is applicable in the shallowest tide flats, and in the deepest water where operations are liable to be carried on. The last 1 000 ft. of the Coos Bay jetty tramway was built in water 26 ft. deep at low water, with piles 80 ft. long, and which penetrated 30 ft. into the sand. It is to be noted that at Galveston the tramway system was adopted after years of trial of other devices.

The swells and waves of the Pacific, and especially along the coast of Oregon and Washington, would, it is believed, render it impossible to carry on the work of jetty construction as it is carried on at Charleston and the other points named by Captain Black. Out here, there probably would be not to exceed twenty days in a year when the method of towing out and sinking mattresses described by Captain Black (*Transactions*, Vol. XXIX, pages 266 and 267) could be successfully carried out, and these days would be bunched in the summer.

I am inclined to believe that the sand movements on the Atlantic Coast are not nearly equal in magnitude and rapidity to the sand movements on the Pacific Coast. On the Atlantic Coast, there seems to be a decided general resultant sand movement to the south; on the Pacific there is no such general resultant movement, or, if there is, it is so modified by local circumstances as to be indistinguishable.

The supporting power of the sand appears greater on the Pacific Coast than on the Atlantic. So great is this supporting power that

some of our ablest engineers question the necessity of putting any mattresses down for the support of the rubble mounds. It is probable that the South Atlantic sands are finer and lighter than are those of the Pacific, thus necessitating the very wide mattresses described.

On the other hand, the channels naturally developed through the bar sands on the Atlantic Coast appear to have a far greater persistence than have similar channels through the bar sands of the Pacific.

The important function of jetties to impound the moving sands does not seem to be recognized on the Atlantic Coast with the force that it is here. This is particularly evidenced by the plan adopted at Charleston, where, instead of impounding it outside of both jetties, it is proposed to keep it moving to the south across the inner ends of the jetties, where the width between them is greatest. I should fear that such a condition would result in the formation of an inner bar or shoal, materially limiting the capacity of the harbor.

The work at the Cape Fear River appears to have been eminently successful. I should judge that the entrance to the river received very valuable protection against storms from the north and east, from Smith's Island and the Frying Pan Shoals, and that the maintenance of the good entrance by dredging would be comparatively easy. One of the lessons learned in this work was also taught by our Pacific Coast works, *i. e.*, that it is better to build up gradually from the bottom over a long line than to push the completed structure bodily to the front.

The work at Charleston is certainly interesting as to plan, methods, and results. It is evident, however, that the work is far from completed. The wisdom of leaving the jetties low near their inner ends may well be questioned, and it was well, in formulating the plan, to leave this height as well as the length of the jetties problematical. It looks to me as if the adopted width between the ends, 2 900 ft., would require the entire tidal flow to pass through to secure and maintain the deep-water channel aimed at. This will necessitate building both jetties up to full high tide.

The mattresses of logs have, as pointed out by Captain Black, the great demerit of comparative inflexibility. Experience on the Pacific Coast would indicate that a better construction would have been a mattress, 3, 4, or 5 ft. thick, of brush fascines and poles, well tied and wired together.

At St. Johns, a study of the comparative charts and a knowledge of the resultant movement of sands and channels to the southward rather indicates that it would have been wise to adopt the southern entrance channel of 1879 as the one to be improved. From the comparative charts and profiles and Captain Black's statements of the results accomplished, it is evident to me that it will require the entire tidal flow to pass in and out between the jetties, to develop and maintain the maximum channel over the bar with the adopted width between ends of jetties.

The existence of the two channels branching near the ends of the jetties is indicative of the fact that there is not at present a proper corelation between the tidal flows, the active forces and the width and height of the jetties built to control and direct these forces.

Captain BLACK.—There are a few statements made by Captain Symons which I think will bear further discussion. Captain Symons names the method of jetty construction from tramways "The Pacific Coast System," and that from floating plant "The Atlantic Coast System," it is presumable, simply as a convenient mode of distinguishing them apart. Neither system was devised or used exclusively on either coast. Both systems have been used for many years abroad, and both are in use on the Atlantic Coast. The tramway method has been applied on the greatest scale at the mouth of the Columbia River, Oregon, and there its details have been most skillfully elaborated.

The decision as to which system is best adapted for any particular work must be based on the question of relative economy. The tramway system is certainly best for stormy sites, and where the available funds are sufficient in amount, and reasonably continuous in supply. Where the amounts available are small, and the supply intermittent, it is manifestly advantageous to adopt a system in which the capital sunk in destructible and non-removable plant is as small as possible. The improvements described in the paper were started in the days of small and very irregular appropriations, and that is doubtless the reason for the construction methods adopted. Later, when large and more regular appropriations became available, the adoption of the tramway method was found to involve too great an outlay to be advisable at the stage to which the works had been advanced, under the conditions of wind and weather prevailing.

The wide divergence of the completed jetties in type, which Captain Symons finds, is not evident. On both coasts, the jetties are of rubble, as large as can be handled economically, on a mattress foundation, and are built to the height necessary to control the required volume of flow, and no higher. In all cases the height is determined by the conditions at the particular work. Captain Symons' statement as to the results of the experience of the engineers of the Pacific Coast would seem to be somewhat sweeping. It is hardly likely that anyone would admit that his mind is of so inflexible a texture that it must insist on one particular type of work regardless of local conditions.

He is also somewhat contradictory regarding the value of thick mattresses. In one paragraph he states that the "conclusion arrived at concerning the proper type of jetty calls for a "thick brush mattress foundation." Elsewhere he states that "some of our ablest engineers question the necessity of putting any mattress down for the support of the rubble mounds." From this it appears that, after all, the mattress is regarded rather as a necessary evil. It has been the experience of the writer, that where not covered promptly by sand or silt, the mattress was gradually destroyed by the teredo. Where any great thickness was used in a jetty, the destruction of a portion of the wood, and the compression of the remainder, caused a gradual subsidence of the jetty crest, and necessitated a continued building up with stone. For these reasons he prefers a tightly compressed mattress as thin as consistent with the requisite degree of strength and impermeability.

The use of a jetty for impounding sand is also of doubtful value where large volumes of sand are moving. It is a simple impossibility to stop the entire sand movement of the Atlantic Coast for any prolonged period. If the sand cannot be induced to move past the jetties without blocking the channel, the necessity of further jetty extension is simply a question of time, unless dredging be resorted to, as abroad.

The Charleston and St. Johns works are not yet completed, and therefore no conclusions can be drawn from them definitely, no criticism on the height of jetty is possible, for no height has as yet been fixed upon. The latest advices from both works show that the improvement of the jetty channels has continued since the paper was written. At Charleston there is now a straight channel from the sea to the city 15 ft. deep at low water, and 18 ft. deep at low water for all

but 1 000 ft. At the St. Johns the channel has also greatly improved. The forking of the channels at the entrance of the St. Johns jetties was the necessary result of the rolling out of the immense volume of sand which lay between the jetty sites, the deeper channels forming where the jetties were most affective, close alongside.

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662.

(Vol. XXX.—December, 1893.)

RAILWAY TERMINAL SYSTEMS.—DISCUSSION ON PAPER No. 612.*

By C. O. GLEIM.

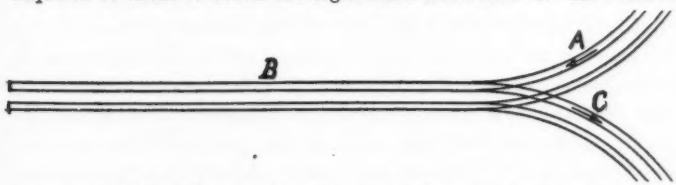
C. O. GLEIM, Cor. M. Am. Soc. C. E.—In revising the remarks made by me orally at the International Engineering Congress, I suppress so much of them as referred to some misunderstandings contained in the advance copies of the paper, which have now been corrected.

The new terminal system for the sister cities of Hamburg and Altona, with the Hamburg part of which I have been officially connected for several years, will form a very interesting case of terminal arrangements for large cities. The change at present contemplated, and partly executed, is the consequence of the absorption by the Prussian Government of all the railways entering the two cities, with the one exception of the Lubeck line. The various lines entering on the Hamburg side will be joined in a central station, from which the trains will pass on, over the connecting railway, through three intermediate stations, to the term-

* "The Rearrangement of the Railway Terminal System at Altona, with Special Reference to the Avoidance of Grade Crossings." By R. Caesar, Member of the Royal Board of Railroad Directors at Altona, Prussia. *Transactions*, Vol. XXIX, page 295.

inal at Altona, while the trains entering on the Altona side are to pass over the same connecting railway, using the same intermediate stations, and terminating in the Central Station of Hamburg. The overlapping system thus formed will be very similar to that of the existing Metropolitan Railway (Stadtbahn) of Berlin. The same similarity will exist in the carrying through, in both cases, of four independent railway tracks, of which two will be for city traffic, and two for through passenger traffic and freight. The connecting railway between Hamburg and Altona, which is now a double-track line, will at the same time be raised so as to abolish present grade crossings of streets.

In carrying out the system thus outlined, a complication arose on the Altona side, which forms the subject of the paper. Local influences caused the terminal station of that city to be retained as near as possible to its old position, and this necessitated, instead of an ordinary through station, the arrangement of a "pocket station," or, as it is termed in Germany, a "head station," where the trains reverse their direction, and go out at the same end from which they entered. A station of this kind necessitates inconvenient crossings of main tracks already when forming an intermediate station of a merely double-track line. An arrangement like the following diagram, with one track crossing, would not be sufficient; for the train coming in on the right-hand track from *A*, and reversing on the track *B*, would reach the left-hand track *C*, as shown by the arrows, and another crossing would be required to make it reach the right-hand track near *C*. How much



more complicated the crossings become in the case of a four-track line, as at Altona, is shown in the paper. Fortunately, it was possible, without exceeding grades of 1 in 100, to raise and lower the tracks so as to arrange a system of over and under grade bridges, and avoid practically all grade crossings between main tracks. Although the well-known example of the Cannon Street Station in London as an intermediate "pocket station" between London Bridge and Charing Cross, has proved that such a station can, even under a very heavy

traffic, be worked with level crossings of the tracks, if protected by a well-regulated signal system, there can be no doubt that, where practicable, a solution based on passing the tracks by bridges over one another, as at Altona, is to be preferred. Perhaps it was a mistake in this case to have given way to local interests so far as to accept a situation precluding the arrangement of a through station; but the "pocket station" having once been accepted, the system, with the avoidance of grade crossings, has been carried through in the most consistent way, and Plate I (Vol. XXIX, page 296) is well worthy of a thorough study. If drawing is the universal language of the engineer, requiring no translation, this drawing will give a better idea of the work treated in the paper than any lengthy description could do.

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LOADINGS FOR RAILWAY BRIDGES.—DISCUSSION ON PAPER No. 618.*

By WARD BALDWIN, J. A. L. WADDELL and C. D. PURDON.

WARD BALDWIN, M. Am. Soc. C. E.—The loading incorporated in a set of railway bridge specifications is usually based upon the weights and wheel spacings of the heaviest engines and cars used or likely to be used on the particular railway. A sufficiently extended list of the loadings now specified for railway bridges may therefore be regarded as a reflection of the combined judgment of railway engineers as to what loadings should be specified to meet their needs; and a study of such loadings would appear to promise more fruitful results than a study of actual locomotive loads. The systematic efforts of J. A. L. Waddell, M. Am. Soc. C. E., to secure the adoption of a set of standard loadings for railway bridges, have directed special attention quite recently to this subject, and the data in Mr. Purdon's paper are of interest as they bear directly upon this question; but, so far as known to the writer, a classified compilation of specified loadings, although doubtless often made, has not yet been published. Such a compilation would appear

* "Comparison of Modern Engine-Loading with Standard Specifications for Spans from 10 to 200 Feet." By C. D. Purdon, M. Am. Soc. C. E. *Transactions*, Vol. XXIX, page 426.

to be the necessary preliminary to an intelligent discussion of standard loadings, and the writer therefore ventures to add to Mr. Purdon's statistics as complete a list of bridge loadings as he has been able to collect. It is thought this list will be valuable as a record of the present opinions as to proper bridge loadings, and will furnish data for some interesting deductions. This list will also show that the complaints of the bridge computers against needless multiplication of loadings are not without cause.

A concentrated loading enables the railway engineer to secure the proportioning of his bridges to sustain, as near as theory can decide, the exact loads that will come upon them. It is this fact that has led to the general use of concentrated loadings by railway engineers, rather than any desire on their part to be ultra theoretical. To this fact also must be ascribed the much-complained-of diversity of loadings, because the attention of the railway engineer has been directed rather to the determination of a loading suitable for his road, than of one that would make the work of the bridge computer easy. This method adopted by the railway engineer for selecting bridge loadings is undoubtedly the only rational one, and will not, therefore, be abandoned simply because it increases the labor of bridge computers. But there is no advantage in adhering strictly to the exact wheel weights and spacings of the actual loadings, as is done for example in loading 90 of the table. The real distribution of the loading is seldom, if ever, the same as found by weighing the wheel weights when the train is at rest; and the stresses produced by the actual loading would, so far as can now be known, be as near those given by a typical loading with wheel spacings in even feet, and wheel loads to the nearest 1 000 pounds, as those given by a loading with dimensions more minutely agreeing with actual static dimensions. This consideration would seem to show that it would be no sacrifice of accuracy to reduce unnecessary drudgery in computations by rounding off the figures. And other facts, such as differences in allowed unit stresses, lead to the conclusion that substantial accuracy in results may be secured so long as the general distribution of the actual loading is observed in the typical loading, even though the latter may differ considerably from the actual load in detail. Thus it would seem reasonable to expect that a comparatively small number of standard loadings might replace the large number of loadings in use at present. That a

great saving of labor for the bridge computers would result from the general adoption of a set of standard loadings is evidenced by the variety of loadings given in the list above; and there is no question but that such loadings would be readily recognized as standard, provided they were so selected as to cover substantially the same ground as the present specified bridge loadings.

The above list, comprising the loadings now specified by one hundred independent railway systems of the United States and Canada, seems comprehensive enough to serve as a basis for a study of at least some of the conditions a set of standard loadings should fulfill. In the list, the loadings used by five of the Canadian railways (Nos. 79 to 83 of the list) are included. All Canadian railways that receive government aid, and most of them do, are required to use this loading, which is that contained in the general specifications for railway bridges issued by the Chief Engineer of the Government railways of Canada; and this loading may therefore be considered as the established standard for Canadian railways at this time. These five railways will therefore be disregarded in the succeeding remarks, and attention will be confined to the 95 remaining railways, which are all in the United States. Among these 95 railways, 10 (Nos. 91 to 100 of the list) specify some kind of uniform load with, in some cases, additional excess loads. As the actual distributions of the corresponding concentrated loading from which these uniform loadings have been derived are not given, these 10 loadings will also be omitted in the present inquiry. Among the 85 remaining railways—

71 specify only one kind of loading.
10 specify two kinds of loading.
4 specify three kinds of loading.
82 specify a loading made up wholly or in part of consolidation engines.
12 specify a loading made up wholly or in part of passenger engines.
5 specify a loading made up wholly or in part of decapod engines.
3 specify a loading made up wholly or in part of ten-wheel engines.
1 specifies a loading made up in part of mogul engines.
3 require a uniform load to precede as well as follow the engines.
82 do not require any load to precede the engines.

Among the 82 railways that specify a loading made up wholly or in part of consolidation engines—

4 vary the weights on the drivers.
78 do not vary the weights on the drivers.
9 vary the weights on the tender wheels.
73 do not vary the weights on the tender wheels.

77 specify two consolidation engines and a uniform load.
3 specify a train of consolidation engines.
1 specifies two consolidation engines and wheel-loads for train.
1 specifies the 4 driver-loads of a consolidation engine, and a uniform load.

In the above enumeration, railways 20 and 34 of the list are counted twice, because they specify two loadings, each consisting of two consolidation engines and a uniform load.

Of the 77 loadings of two consolidation engines and a uniform load, there are—

27 that are each used by 1 railway.
4 " " 2 railways.
3 " " 3 "
2 that are each used by 4 railways (Cooper's "Lehigh Valley" and P. R.R. specifications).
1 that is used by 9 railways (Cooper's Class "A").
1 " 16 " (Cooper's Extra Heavy "A").

These figures make it clear that the only loadings that have as yet been at all generally adopted are those given in Mr. Cooper's bridge specifications.

Out of these same 77 loadings—

1	requires a	22 000-lb.	driver load	with a	2 240-lb.	uniform	load.
1	"	23 000	"	"	3 500	"	"
12	"	24 000	"	"	3 000	"	"
1	"	24 640	"	"	3 000	"	"
3	"	28 000	"	"	3 000	"	"
1	"	28 000	"	"	3 500	"	"
1	"	28 600	"	"	4 000	"	"
18	"	30 000	"	"	3 000	"	"
1	"	30 000	"	"	3 500	"	"
14	"	30 000	"	"	4 000	"	"
1	"	30 000	"	"	4 200	"	"

1	requires a	31 000-lb.	driver-load	with a	4 000-lb.	uniform	load.
1	"	32 000	"	"	3 600	"	"
2	"	32 500	"	"	3 500	"	"
1	"	34 000	"	"	3 000	"	"
1	"	35 000	"	"	3 500	"	"
4	"	35 000	"	"	4 000	"	"
1	"	36 000	"	"	4 000	"	"
2	"	average 37 000	"	"	4 000	"	"
6	"	40 000	"	"	4 000	"	"
1	"	44 000	"	"	3 200	"	"
1	"	average 36 600	"	"	3 000	"	"
2	"	only gross weights of engines			3 000 4 200	"	"

1	specifies a	uniform	load of	2 240 lbs. per ft.
37	"	"	"	3 000 "
1	"	"	"	3 200 "
6	"	"	"	3 500 "
1	"	"	"	3 600 "
29	"	"	"	4 000 "
2	"	"	"	4 200 "

If the 85 loadings that form the basis of this paper can be accepted as fairly representative of the loadings that are needed by railway engineers, the conclusions that the comparisons given above seem to justify are :

1. A loading consisting of two consolidation engines followed by a uniform train-load should be the standard form of specified loading; but this should be supplemented by a heavy passenger engine for short panels.

2. In a set of standard loadings the uniform load should vary by increments of 250 lbs, from 3 000 lbs. to 4 250 lbs. per foot.

3. The driver-loads should vary by increments of 3 000 lbs. from 24 000 to 36 000 lbs.; and by increments of 4 000 lbs. from 36 000 to 44 000 lbs. The tender-wheel loads should vary by increments of 1 000 lbs. from 17 000 to 23 000 lbs. The truck-wheel loads should vary by increments of 1 000 lbs., from 14 000 to 20 000 lbs.

4. The driver and tender wheels in a given loading should be given uniform weights.

The difficulties in the way of arriving at a suitable set of standard engine-loadings do not seem to be very great. A large majority of the railways now specify consolidation engines, and it only remains to secure an agreement as to certain standard wheel-spacings and graded wheel-loads. A problem of more difficulty, perhaps, is the selection of the uniform train-load to be coupled to a given engine-load, because the uniform load now used by many railways does not seem to bear any general relation to the engine-loading. Mr. Purdon has called attention to the fact that the Pennsylvania Railroad loading, consisting of two consolidation engines, followed by a uniform train-load, produces smaller chord stresses in a long-span bridge than the train-load with the engines off the span. In this loading, the aggregate engine-loads, if distributed uniformly over the engine-wheel base, would be only about 3 700 lbs. per foot, while the train-load is 4 000 lbs. per foot. A case of the extreme opposite ratio of engine-load to train-load is the loading for the Atchison, Topeka and Sante Fé Railroad, in which case the aggregate engine-loading uniformly distributed over the engine-wheel base would be about 5 200 lbs. per foot, while the train-load is only 3 200 lbs. per foot. It will be readily perceived from an inspection of the list of loadings given above that in many cases the heavier engines are attached to the lighter trains, and *vice versa*. Thus it would appear that each uniform load should be coupled to several of the engine-loads somewhat as follows:

The 3 000-lb. uniform load to each of the engines having from 24 000 to 36 000-lb. driver-loads, and each of the other uniform load from 3 250 to 4 250 lbs. per foot, to each of the engines having from 30 000 to 44 000-lb. driver-loads.

Using the wheel spacing given by Mr. Waddell on Plate XVI, *Transactions*, Vol. XXVI, p. 90, the set of loadings resulting from the above combinations would be (see table on page 521).

The tenders for the passenger engines are the same as for the corresponding consolidation engines. The engine-loads in this set of loadings do not differ much from those proposed by Mr. Waddell, but they agree somewhat more closely with the driver weights that are used in current specifications. The plan of coupling one engine-load to several uniform loads is a radical departure from the plan adopted by Mr. Waddell, of coupling each engine-load to a single uniform load, the uniform load increasing regularly with the driver-load of the engines coupled to it. It does not seem possible to devise a system of

| Two Consolidation Engines. | | Uniform load. | Passenger Engine. | | |

loadings on this latter plan that will agree with the conditions of actual traffic. For example, consolidation engines having driver-loads of from 24 000 to 36 000 lbs. are now in use on many railways, where the heaviest cars hauled are of 60 000 lbs. capacity, weighing about 2 650 lbs. per foot, so that present traffic conditions seem to require that the uniform load of 3 000 lbs. should be coupled with each engine-load up to those having at least as much as 36 000-lb. driver-loads. This seems the more necessary when it is remembered that the uniform load of 3 000 lbs. is about 12% in excess of the weight of a train of loaded cars of 60 000 lbs. capacity, and, therefore, represents a load seldom reached, except on roads carrying ore trains, while engines having as high as 36 000-lb. driver-loads are in common use to-day. While the coupling of several engine-loads to each uniform load multiplies the number of loadings, still this is a matter of no great moment, for the most important advantage to be gained from a set of standard loadings, viz., of restricting the types of engine-loadings to a small number and simple dimensions, would be attained by using such a set of loadings as are given above.

The suggestion is offered, that in specified loadings where mogul or 10-wheel engines are used, consolidation engines with equal driver-loads may be properly substituted; and where decapod engines are used, consolidation engines with equal aggregate weight may be substituted, if a set of standard loadings made up of two consolidation engines and a uniform load should be adopted. The writer ventures to express the hope that the Society will regard this problem of sufficient importance, and its satisfactory solution promising enough to warrant its consideration by a special committee.

J. A. L. Waddell, M. Am. Soc. C. E.—In discussing this paper I merely wish to point out that Mr. Purdon's curves on Plate II confirm a statement of mine, viz., that, as far as I know, "Class U" of my proposed "Compromise Standard System of Live Loads for Railway Bridges," gives results a trifle greater than those obtained by adopting two of the heaviest engines yet built followed by a train of cars as heavy as are yet used on any track. I have plotted the equivalent uniform loads for "Class U" on Mr. Purdon's Plate II, and find that the resulting curve passes throughout its entire length a little above the curves for the heaviest loads there given. Again, I have plotted also on the same plate the curve for the lightest load of my proposed system, viz., "Class Z," and find that it agrees quite closely

In the following list each railway is given a number which is placed immediately after the title of the road. The wheel weights are expressed in units of 1 000 lbs., and the uniform loads are expressed in pounds per linear foot:

| | | |

| | | |

| | | |

with the curve for the lightest loading given on the plate, viz., that for the New York Central and Hudson River Railroad.

Now it is probable that Mr. Purdon, in preparing Plate II, chose the heaviest engines he could find for the greatest loads, and the lightest heavy engines used on trunk lines for the smallest loads; hence it seems fair to conclude that my proposed "Compromise Standard System" gives the heaviest and lightest loads that are needed at present in designing bridges. In order to make the system suitable for the Santa Fé specifications, however, I have added a "Class T," to be used for floor systems and primary truss members only, the engines for which correspond approximately with the typical ones adopted in the Santa Fé specifications for 1893.

The diagrams of equivalent loads, etc., for the proposed "Compromise Standard" will be issued soon.

C. D. PURDON, M. Am. Soc. C. E.—My paper was prepared simply to show how a few engines, thought remarkable enough to exhibit, compared with the loads which bridges were supposed to carry, and in this respect was hardly open to discussion. I had no intention of reflecting on standard loading, or starting anew a discussion on that subject.

Mr. Baldwin's table gives very valuable information as to the difference of opinion in bridge loading, and, so far as I know, is the only attempt ever made at a classification of the same.

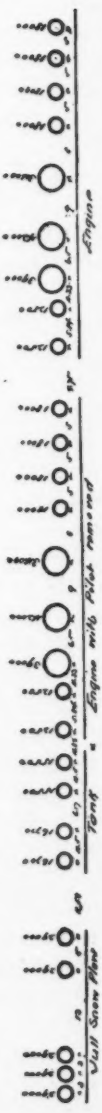
Mr. Baldwin says that a study of specified loads would appear to promise more fruitful results than a study of actual loads. Perhaps so, but certainly the actual loads should also be studied for comparison; it is the actual load which comes on the bridges.

I think diagrams of the engines in Mr. Baldwin's table, prepared as were my diagrams, would show that the uniformity of loading so much advocated by Mr. Waddell really exists, but is not recognized. A diagram thus prepared would give a number of groups of loadings, each group of which might be covered by a single typical loading—for instance, in my Plate I, leaving out the A. T. & S. F. and Wabash, the other loads come practically into three groups, the highest of which is covered by Mr. Waddell's "Class U."

The diagram would enable the engineer of any road to see at once, without spending any time in figuring, into what class of loading his specification came, and would do more towards Mr. Waddell's proposed uniformity than any amount of discussion and figures.

It would be considerable labor to prepare such a diagram, but it could be divided up among several members, were any sufficiently interested in the subject to devote some time to the calculations. I could undertake 5 to 10 loadings myself.

I notice in Mr. Baldwin's table that only 3 specifications out of 85 require any load to precede the engine. Now, with roads using snow plows, this might make an important difference. Mr. Temple, Assoc. M. Am. Soc. C. E., and I are now calculating the effect of a Jull snow plow—which was on exhibition at Chicago—followed by two engines, and find it makes quite serious differences in the strains in some bridges, especially in the floor. The plow has an ordinary tank behind it, and this tank is pushed by two engines, the leading engine having its pilot removed. The following is a diagram of the concentrations:



This loading increases the strain by the following:

On 10-ft. span	.....	24 %
On 15 "	.....	22½ "
On 20 "	.....	15 "

On 30-ft. to 40-ft. spans, no difference; and on spans from 40 to 90 ft., about 2 or 3 per cent. All these on stringers or plate girders.

Our figures on truss members are not yet complete. So far we find an increase of 6% on a span of 164 ft.

These increases are over the two engines on the diagram, followed by 3 200 lbs. per linear foot.

I do not see why the uniform load following the engines should be varied to suit the engines, unless in case of a mineral road, or one which does not exchange cars with any other road.

Under the present system of traffic there is nothing to prevent a car, loaded in New York, going over every road of the same gauge in the United States and Canada; and, as Mr. Baldwin says, this extreme load is about 2 650 lbs. per foot; so that 3 200 should be a sufficient typical load, unless in the case of a road using special ore cars.

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664.

(Vol. XXX.—December, 1893.

SURVEYS FOR RAILWAY LOCATION.—DISCUSSION ON PAPER No. 619.*

By GEORGE R. HARDY, G. B. NICHOLSON, C. O. GLEIM, ARTHUR PEW, A. BRYSON, W. R. KING and F. A. GELBCKE.

GEORGE R. HARDY, M. Am. Soc. C. E.—The very excellent paper that is now under discussion divides the work into four parts, namely: Reconnaissance, General Survey, Detailed Survey and Field Location.

Personal experience reminds us that closely following the examination of a country, which the author designates as reconnaissance, we are accustomed to survey some trial line which will afford a base for detail examination, until superseded by the location work. For our long railroad lines, and particularly the transcontinental, geographical exploration is necessary before such reconnaissance. The information thus obtained enables a selection of passes or features of the probable routes to be further investigated, these belonging to the class of more stupendous obstructions.

The exploration indicates the places for profitable reconnaissance. The reconnaissance determines which general routes are worthy of a

* "Surveys for Railway Location." By F. A. Gelbcke, Engineer of Government Railways at Cologne, Prussia. *Transactions*, Vol. XXIX, page 429.

trial survey. The trial lines with topography provide data and maps for projecting a location line. Trial lines are usually run by angles and courses, while the location line is staked every 100 ft. in curves and tangents. Engineers of the highest grade and experience are demanded for personal examination of the country, and on their ability and decisions much depends.

Our methods offer quite a contrast with the suggestions under discussion.

First.—As to instruments. For exploration—barometer, sextant, compass and camera. For reconnaissance—barometer, compass and hand level. For trail lines—transit, level, tapes, chains and rods; recently the stadia work has been used. For location—transit and level, etc., etc.

Second.—Our corps of engineers are not so amply provided with technical members, nor are we able to avail ourselves of such well-advanced mapping.

Third.—We are not accustomed to depend so much on topography as to establish the location line, beyond the necessity for careful examination of the proposed location in the field, with freedom to make such changes as are warranted.

G. B. Nicholson, M. Am. Soc. C. E.—Mr. President, I think the gentleman who preceded me has not comprehended the German methods. Probably Mr. Gleim can correct me if I am not right, but I understand that in Germany topographical surveys of the country are so complete and detailed that a railroad line may be located on published maps which would be as perfect as the usual preliminary survey made without the aid of such maps.

C. O. Gleim, Cor. M. Am. Soc. C. E.—You can in some of the provinces; in a great many cases the surveys of the Government have not been completed.

Arthur Pew, M. Am. Soc. C. E.—It is certainly advisable that the country should be thoroughly studied before the line is finally located. The locating engineer is an important factor in making or marring the fortunes of a road, and, in order that he may obtain the best line, he should have all the information that would be of service to him.

The methods proposed by Mr. Gelbcke for obtaining this information are slower and more expensive than those that are customary in this country. The reason for this is, that he does not fully utilize the

skill and judgment of the locating engineer, but has an expensive corps of engineers collecting information, a large proportion of which an expert locating engineer would see from a simple inspection of the country was unnecessary.

It is customary in this country for the locating engineer to make a careful examination of the country through which the line is to run. He has with him, of course, an aneroid barometer, a pocket compass, and sometimes other instruments. The country may be such that he can quickly decide on the best route, or there may be several possible routes, between which he cannot decide without an actual survey. As soon as he decides which line he wishes to run first, a corps is put in the field, and the line run in the usual manner by setting numbered stakes 100 ft. apart.

The work of an ordinary corps is from 1 to 10 miles of line a day, depending on the character of the country, efficiency of the corps, etc. The cost of a corps varies from about $800 to $1 500 per month, with the number of men and salaries paid.

There is rarely any objection to staking out the preliminary lines run in this country, for property owners generally understand, or are informed, that each is only a preliminary line, and that the final location may possibly be several miles away. The fact that several preliminary lines are usually run, and the consequent uncertainty as to which will be followed most closely by the final location, has a tendency to prevent any considerable amount of extortion on the part of landowners. These preliminary lines are plotted on a scale suitable to the character of the country and, being staked out on the ground, serve as base lines by means of which the necessary topography can be taken rapidly and accurately. The locating engineer, with the assistance rendered by these maps, can select the best route and locate the line at a minimum of expense.

This is the usual American method. Its advantage over that proposed by Mr. Gelbcke is that it obviates a great deal of unnecessary work and expense, and in general gives excellent results. So far as my own observation extends, American roads are located fully as well as those of Europe.

In my own experience, in some of the southern and western States the total cost of location, including all preliminaries, has rarely amounted to as much as $150 per mile of located line, even where the

country was thoroughly studied; and, in some instances, the cost has not exceeded half that amount.

A. Bryson, M. Am. Soc. C. E.—Mr. Gelbcke has given us a very interesting paper on surveys for railway location, but the great detail of his method will appear rather extreme to his American *confrères*. One is greatly impressed with its thoroughness, but it is very questionable whether the results of that system, practically carried out, would be any better than one not so elaborate under competent direction.

In the method outlined by the author, the entire subject is more and more developed by a series of examinations and resulting maps, until the selection is finally made by a process of elimination. All this requires time, patience and draughtsmen; also, the entire absence of an American board of directors.

The reconnaissance is unquestionably indispensable, and if the previously mentioned board of directors have not already determined on the general points to be touched, so practically defining the route, the engineer will have an opportunity to show his genius for "general" location in contradistinction to "detail" location; if he possesses the "diagnosing" faculty, his personal preliminary work will save much time, so that the author's "General Survey" and "Detailed Survey" may be brought together into one.

The author recommends "in the case of narrow valleys, always to consider both slopes of the valley in the extent of the survey." If this is intended to mean simply the taking of general notes sufficient to intelligently determine questions of line fitting which may arise, the writer's views are in hearty accord, but not if carried to the extent that was done in one case of which he knows. A railway line was located in a valley varying, maybe, from 200 to 1 500 ft. wide, having bold hills on each side, so that there was no possibility of doing anything except to stick to the flat valley. Nevertheless, cross-lines were run 500 ft. apart, from up on the hill on one side to some equally necessary point on the other, throughout the entire distance of 15 or 20 miles.

There can be no "hard and fast" rule applicable to all occasions. If the engineer engaged on such work is possessed of that personal acumen, like a physician's intuitive ability to diagnose diseases, much time and money will be saved; it is aided by education, study and

practice, but they do not entirely make up for its absence; otherwise, one physician would be as able and successful as another, and, among engineers, there would exist a like equality.

The fact that location may make the difference between dividends and bankruptcy when the road is in operation is difficult to impress upon the average director's mind, but the engineer should insist upon a most careful and thorough personal investigation before he sends a party into the field. For this purpose a hand level and compass, or other handy instrument, in the hands of a man who knows country when he sees it, will settle questions of choice of routes in much less time than exhaustive barometric surveys, as advocated by the author; and when supplemented by some flying levels to critical points will, in the writer's opinion, be more satisfactory, his experience with the aneroid having generated a feeling in his soul somewhat akin to distrust.

The author's advocacy of contours and paper location is most cordially endorsed. Possibly his service, on two separate occasions years ago, under "practical" men impressed upon the writer's mind the absolute necessity of experimental work and the contour map, as well as the great saving in time and work they effect. Each of those men "located as he went along"; if the line happened to "hit about right," "go ahead"; if not, and in rough country it was generally "not," we had to "back up" and try again.

The engineer's judgment and perception are requisite in taking the notes, in making the map, and in laying the line. His science and knowledge will both find occupation, but they do not entirely take the place of that faculty which every successful locating engineer should possess, of selecting and judging line and country, to a degree, without instruments.

Much of the bad location to be seen in the United States is due to interference of directors, local influences, and insufficient time for the preliminary examinations. The writer recalls one case when something more than a month was spent in preliminary work over more than 90 miles of line, part of which was rendered necessary because some one in authority "had an idea" and the engineer's objections were overruled. After the contour map was completed, the location was projected, and work pushed so rapidly in the field, that, notwithstanding the country was very broken, no time was given for revision,

which in one or two places he desired to make, but contractors were at work as soon as the assistants could set the cross-section stakes. This is a common occurrence in this country, however, and is only mentioned to show that the author's system of selecting a route by the slow process of elimination is not generally adapted to our requirements.

A slight additional cost of construction, due to lack of time for all the finer adjustments which extended study might show to be possible, is more than offset by the earlier realization from operation, or at least is so considered by those who control the finances. If the author's words, "the surveys for railroads should therefore not be regarded lightly," could have been impressed upon the minds of American railway directors, we should have fewer instances of bad location.

Colonel W. R. King.*—Forty years ago, Colonel George Escol Sellers, a mechanical engineer, then living in Cincinnati, in connection with a Mr. Whetstone, constructed a kind of velocipede, a two-wheel affair, that would go over the ground and give you a profile, showing horizontal and vertical distances, and do it with a fair degree of accuracy. It could be run at about four miles an hour and give a profile of the country. That instrument was made for the Government, and in some way it got boxed up in Washington, where I found it, a great many years ago, and took it to Willett's Point. It was on exhibition in the Engineer Section of the Government Building at the Columbian Exhibition. I found Colonel Sellers a couple of years ago; he is now living in Chattanooga, Tenn. This idea is re-discovered every little while, but this particular invention was made and tried in 1853, and it is a very creditable instrument; it will pay any one to look it over.

Mr. F. A. Gelbcke.—I have been much gratified by the interesting discussion called forth by my paper, and participated in by prominent engineers, showing that American engineers concur in appreciating the great value of good railway surveys.

In answer to the remark by Mr. Pew, that according to his observations American railroads are located equally well as those of Europe, I beg to say that in Europe, including Germany, the location of railways in former years used to be carried out in a similar manner as in America. It is only within the last twenty years that a change has taken place in Germany, by the frequent adoption of the methods described in my paper.

* Corps of Engineers, U. S. A.

Some twenty years ago I took part in the preliminary work for the St. Gothard Railway, in Switzerland, which gave me an opportunity for recognizing the great value of well-elaborated contour maps. As early as 1862 Mr. Wetli, C. E., had prepared such a map for the St. Gothard Railway, on a scale of 1 in 10 000. This map was successfully used for the great number of studies made, with the object of adjusting the line as well as possible to the difficulties of the case, and as a comprehensive map of the whole territory of the project was referred to over and over again. Nevertheless, the chief engineer, Mr. Gerwig, had contour maps made on a scale of 1 in 2 500 for the further elaboration of the best line; and when the line had finally to be located for construction, the then chief engineer, Mr. Hellwag, did not shun the time and expense of having contour plans made on scales of 1 in 1 000 and 1 in 500. It was only by this means that the design of the St. Gothard Railway could be elaborated with such perfection, as presented to the visitors of the World's Columbian Exposition in some prominent details.

On returning from Switzerland, nearly twenty years ago, and resuming my practice in Germany, I soon found full opportunities for applying the experiences gained in the system of railway location, and my first step was to break with the method previously prevailing in Germany, of prematurely staking out trial lines in the field. The results of the change were highly satisfactory. A large number of younger colleagues, now advanced into prominent positions, after assisting in elaborating and introducing the new method, have gradually propagated the knowledge and application of it over Germany, effecting, as I feel convinced, an important improvement.

The new method advocated does not, however, do away with the requirement of "judgment and perception" in the engineer in charge of the work. The development of the best line of location will leave him full opportunities for displaying these qualities. But he can do this work with much better success, and he can bring proof of the line recommended by him being the most advisable one. In many cases the surface of the country gives so little chance of judging from mere observation, that the best location can only be found by the aid of plans, a fact that only recently I have found confirmed in a most surprising manner.

As to the time and money required for railway surveys according to

the method described, I beg to repeat that they cannot bear comparison with the great advantages and savings effected. And in case there is need of very quick work, that can also be effected under this method by taking regard of the principal conditions of the case, but leaving aside all less important accessories.

If the locating engineer would guard himself against disappointments and waste of money, he should choose for his surveys the way indicated, which is sure to lead to the desired end. That there are simple cases, forming an exception, in which an early staking out of the line in the field may be adopted, has been already remarked towards the end of my paper. But in most cases the early setting out of the line in the field is a mistake, and a thorough elaboration of the project from the general to the detail only to be recommended. I hope that the ideas advocated by me may gain ground with my American colleagues and bear good fruits.

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665.

(Vol. XXX.—December, 1893.)

CALCULATION OF CROSS-SECTIONS.—DISCUSSION ON PAPER No. 620.*

By ARTHUR PEW and FRANCISCO DA SILVA RIBEIRO.

ARTHUR PEW, M. Am. Soc. C. E.—Except in rough or mountainous work, it is rarely the case that a railroad cross-section cannot be measured with sufficient accuracy by simply taking the center height and two side heights.

Whenever these three heights give a correct profile of the surface, no matter what the slope of the ground may be, the cross-section may be reduced to a nearly equivalent level cutting (having the same base and slope ratio) whose height is one-fourth of the sum of the side heights and twice the center height.

The area of this new section will always slightly exceed that of the original section. This is an advantage, as it tends to compensate for the slightly concave surface which the earth, in theory at least, always presents to a railroad excavation or embankment.

Let a and b represent the side heights, and c the center height of a

* "A New Method of Calculating Cross-Sections of Roads and Railroads." By Francisco Da Silva Ribeiro, Director of Public Works, Aveiro, Portugal. *Transactions*, Vol. XXIX, page 447.

cross-section. Reduce this to a level section, making its height

$$= c' = \frac{a + b + 2c}{4}.$$

The area of the level section will exceed that of the original section by $d^2 r$, where d = the difference between c and c', and r = the ratio of the horizontal distance of the side slope to the vertical distance.

If desired, a table can be easily calculated giving the amount of this excess for different values of d, and from this table the proper corrections can be taken; but on moderately sloping ground, the excess is so small that it may be neglected.

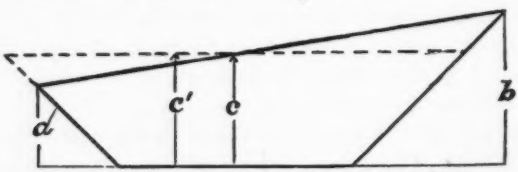
The advantage of reducing sloping cross-sections to equivalent level ones is that the end areas need not be calculated at all. The cubic contents can be taken directly from tables, and corrected for longitudinal slope, as explained in several text books on the subject.

I believe the formula given to be original. By its use the calculation of excavation and embankment becomes a very small affair, as, after a man becomes familiar with it, he can calculate from 500 to 1 000 cross-sections a day of such ground as constitutes at least 95% of railroad work, not in mountainous regions.

This method, however, is only applicable to sections that can be measured by taking the center height and two side heights. On very irregular ground the method of Mr. Ribeiro, or something similar, may be employed.

M. Francisco Da Silva Ribeiro.*—Mr. Arthur Pew, in discussing our method of calculating cross-sections, remarks:

1st. That a simpler system for computing cross-sectional areas in a flat country consists in reducing each section to a nearly equivalent level cutting, whose height, $c,' = \frac{a + b + 2c}{4}$.



2d. That the surface so calculated will always be slightly in excess of the exact area, but the excess, whose value is represented by $d^2 r$, or $\frac{d^2}{t}$, d being the difference $c' - c$ of the two center heights, is so small on

* Translated from the French by Foster Crowell, M. Am. Soc. C. E.

moderately sloping ground that it may be neglected, and for other cases a table can be prepared giving, for different values of d, the correction $\frac{d^2}{t}$, which is to be deducted, to obtain the correct area.

3d. That the method of equivalent level cuttings enables one person to compute easily from 500 to 1 000 cross-sections in a day.

4th. That our method is not advantageous except in rough ground, where the system of three heights cannot well be employed, and that, even there, some other system would give as good results.

The writer thanks Mr. Pew for his able criticism, and will now endeavor to answer him.

The process by the three heights is of course very ingenious and simple, but it requires previous plotting of the sections; whereas, in our method the plotting is not indispensable. In comparing the number of sections which it is possible to compute per day, the time spent in plotting must be taken into account; with our diagram one employee can calculate 200 sections per day, and the writer does not think it would be possible for him to plot and calculate the same number by the three-heights method.

As regards accuracy, furthermore, Mr. Pew's method is not to be compared to ours, for the expression $\frac{d^2}{t}$ varies, not only with the inclination of the surface, but also with the center height; really the exact value of the height of section reduces to—

$$y = \frac{c + l\,t}{\sqrt{1 - \frac{i^2}{t^2}}} - l\,t$$

l being the half width of platform, and i the slope of the surface; the difference—

$$y - c = (c + l\,t)\frac{1 - \sqrt{1 - \frac{i^2}{t^2}}}{\sqrt{1 - \frac{i^2}{t^2}}}$$

$$= \frac{i^2}{t^2} \times \frac{c + l\,t}{1 - \frac{i^2}{t^2} + \sqrt{1 - \frac{i^2}{t^2}}}$$

We see that this difference increases with $\frac{i}{t}$ and with c. Let us suppose a case of a fill on ground inclined at $\frac{1}{3}$; making $t = \frac{2}{3}$ and $i = \frac{1}{3}$ we deduce—

$$y - c = 0.177\ (c + l\,t);$$

if $c + l\,t = 20$, which corresponds to a fill of 17 or 18 m., we find—

$$y - c = 3.54;$$

and it follows that $\frac{(y-c)^2}{t} = \frac{d^2}{i} = 18.80$.

The error must increase in applying the three-heights' method since c' is greater than y. In our method there are no appreciable errors.

The correction table proposed by Mr. Pew is the weak point of his system.

In conclusion, the author knows no other process that gives the cross-sectional areas on any ground without plotting and with such close approximation.

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666.

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THE GAUGES OF RAILWAY TRACK.—DISCUSSION ON PAPER No. 621.*

By H. G. PROUT, FOSTER CROWELL, E. E. R. TRATMAN and E. A. ZIFFER.

H. G. PROUT, M. Am. Soc. C. E.—I do not rise to discuss this paper at any length, but it ought not to go into the printed records of the Society without a word of protest. Those who have read it will see that the whole argument is a collection of the assertions which we were very familiar with in America twenty years ago, but there is no demonstration. The author says that "economy of construction is principally brought about by the faculty of narrow-gauge roads to adapt themselves closely to the formation of the country and to use steeper gradients and smaller radii," and the economy of construction from the use of lighter materials is particularly dwelt upon. But a 4 ft.-8½ in. gauge railroad can be built as light as a 3-ft. gauge railroad, if you build it for the same character and amount of work. If you want a light secondary road to do a small traffic, with light loads hauled short distances, your rolling stock and your rails and all your structures can be light; but for heavy traffic they must be heavy. The author

* "On the Gauges of Railroad Track in General, with Special Consideration of Narrow-Gauge Railroads." By E. A. Ziffer, M. Am. Soc. C. E., of Vienna, Austria. *Transactions*, Vol. XXIX, page 453.

speaks particularly of the economy of rolling stock. As a matter of fact, a narrow-gauge locomotive will cost more than a standard locomotive per ton of useful weight. Of course, all this is within reasonable limits, but we are speaking of a railroad, built where it is worth while to build a railroad, and not a mill or plantation railroad. The author speaks frequently of the economy of maintenance and operation arising from the narrow gauge, as, for instance, the economy of operating small station buildings, small yards, small everything, but he neglects to mention the very great economy he would derive from having small men to run his locomotives and turn his switches, etc. Finally, his demonstration of the economy in operating expenses is based upon a few railroads cited, in which the ratio of operating expenses to gross earnings is favorable; but he tells us nothing of the character of the traffic or even the rates received for carrying that traffic; and that, of course, is fundamental. Those are special railroads, built and operated under special conditions; it is probable that they pay special rates, and it is possible that, with larger gauge, the ratio of operating expenses to gross earnings would have been still more favorable.

FOSTER CROWELL, M. Am. Soc. C. E.—I quite agree with what Colonel Prout has said. I think he might have said a little more, in calling attention to the practical demonstration of the failure of the narrow gauge in this country, where very few of the many narrow-gauge roads of the last decade are now running as such. There are some, it is true, that are still running, but with a third rail for the standard gauge. A great many narrow-gauge roads have been abandoned, and others, that were built during the craze of ten or fifteen years ago in places where standard gauge might have been, have been remodeled into standard gauge at considerable expense. The reason has been the excessive cost of operation of the narrow gauge, all things considered. The question of the initial cost of construction is not one to be considered by itself. I have recently had occasion in my professional practice to examine a group of minor railroads, some standard and some narrow gauge, all built for the same purpose of obtaining lumber and bark from otherwise inaccessible timber districts, and where the roads are not intended to continue very long in service. Even there the comparison of the working expenses showed that, while the four standard and six narrow gauges had been successful, the operation of the standard-gauge roads

had been much more profitable. Wherever a narrow-gauge road is either in competition or in communication with a standard gauge, it is at a disadvantage; and even in a new country, without competition, the physical argument will generally be in favor of the standard gauge, although, very obviously, conditions are sometimes met with which justify the narrow gauge. The arguments for the narrow gauge, at this time, from our experience, are rather ancient history.

The rise and fall in this country of the narrow-gauge delusion is illustrated in the following little table, which I have prepared to show the comparative mileage at the present time and of ten years ago, when the narrow-gauge movement had just passed its high water-mark. The figures of total mileage given therein are taken from Poor's "Manual of Railroads," editions of 1883 and 1893; the manual does not summarize the narrow-gauge roads, but I have carefully gone over the statements of steam railroads in the two editions and separated the two classes.

It may surprise many to learn from the table that no less than 147 narrow-gauge railroads, with an aggregate length of 9 291 miles, have been either entirely converted to standard, supplied with a third rail, or abandoned during the past eleven years. These roads, "though lost to sight," are, doubtless, "to memory dear" to the confiding shareholders, who were led astray by the same specious arguments that we have had presented anew in this paper.

It is scarcely necessary to add to this record the experience afforded in other countries as to the comparative values of the narrow and the standard gauge, but it may be stated broadly that wherever the two have been introduced into the same territory the standard gauge has proved the best fitted to survive. In the interesting paper presented to this division of the Engineering Congress, upon Railroads in the Republic of Mexico in 1893, Señor E. Prieto Basave, M. Association of Engineers and Architects of Mexico, makes the statement that, while three standard-gauge roads have paid, respectively, approximately 6½, 8½ and 13½ per cent. per annum, the fourth of the group, the Mexican National, which is narrow gauge, has only realized about 4 per cent. It is only fair to say that Señor Basave does not himself attribute the difference in earning power to the gauge, but ascribes it to the road "not being very well managed." He adds, however, that "at the present time it is paying the tribute due to its wasteful construction,

for, notwithstanding its being a narrow-gauge road, it has cost 50% more per kilometer than the Central" (standard gauge):

Railroads in the United States (excluding street railroads).	Miles.	Number.
All railroads in operation in 1882*	112 412	1 538
Narrow gauge in operation in 1882*	9 762	151
Percentage, narrow gauge in 1882	$8\frac{7}{10}$	$9\frac{8}{10}$
Narrow-gauge railroads built during the decade ending with 1892	4 281	102
All railroads built during same period	62 811	2 166
Average narrow gauge per year	428	
Total average per year	6 281	
Percentage, narrow gauge	$6\frac{8}{10}$	$4\frac{7}{10}$
Narrow-gauge railroads built in the three years, 1890, 1891 and 1892	278	12
All railroads built during same period	13 870	
Average narrow gauge per year	93	
Average all roads per year	4 623	
Percentage, narrow gauge	2	$4\frac{8}{10}$
Narrow-gauge railroads either converted to standard 4 ft. $8\frac{1}{2}$ gauge, supplied with third rail, or abandoned, during the decade ending with 1892	9 239	143
Narrow-gauge railroads in operation in 1892 †	4 804	110
All railroads in operation in 1892 †	175 223	2 166
Percentage, narrow gauge	$2\frac{7}{10}$	5
Narrow-gauge railroads converted to standard gauge subsequent to 1892	52	4
Narrow-gauge railroads, included above, used exclusively for light passenger excursion business	190	12
Narrow-gauge railroads doing combined passenger and freight business in 1893	4 562	94
Percentage, narrow gauge compared with all roads	$2\frac{6}{10}$	$4\frac{3}{10}$

* Poor's "Manual of Railroads," 1883.

† Poor's "Manual of Railroads," 1893.

Returning to the United States railroads, it should be noted that the comparisons in the table are based upon the length of road, and not of total track; but as few narrow-gauge roads have second track, and the total length of main track, excluding sidings, in the United States in 1893 could not have been far from 200 000 miles, the percentage of narrow gauge for this year, as given in the table can properly be reduced in the proportion of 200 000 to 175 000 to $2\frac{3}{10}\%$ of the total mileage.

The table shows also, that for the past three years the proportion of narrow gauge built has been very far below the average for the past ten years, and has been confined to short lines averaging 23 miles in length; these figures are probably not absolutely exact, but they have been carefully collated and undoubtedly fairly reflect the passing of the narrow gauge.

E. E. R. TRATMAN, Assoc. M. Am. Soc. C. E.—In this country the necessity and advantages of uniformity of gauge have been proved beyond dispute.

The Billerica and Bedford Railway, instanced by Mr. Ziffer, was changed from 2 ft. to 4 ft. 8½ ins. gauge some years ago.

In ordinary railway service there is little advantage *per se* in the narrow gauge, and the advantages claimed can be secured with standard gauge if proper attention is paid to location, construction and equipment.

It has been amply proved in this country, Australia and India that it is unwise to introduce a second gauge.

Mr. E. A. ZIFFER.—I am indebted to the American Society of Civil Engineers for having afforded me an opportunity, as I was unable to be present at the Chicago Congress, to reply to the adverse criticism raised in the discussion of my paper.

First of all, I may, I think, conclude that Messrs. H. G. Prout and Foster Crowell were laboring under the erroneous impression that I advocated the adoption of the narrow gauge for railroads generally, and that the justification of the advantages was matter of recent date.

This is not so, inasmuch as I showed that in Germany the movement in favor of narrow-gauge roads commenced in 1869, and that in 1870, before the British Railway Union in Liverpool, Fairlie declared that "every inch added to the absolutely necessary width of the gauge increases the cost of construction, the proportion of dead load and the cost of passenger traffic." Nor did I fail to quote the Festiniog narrow gauge which dates from 1832.

My task was to set forth the value of the narrow gauge for lines of subordinate importance, secondary and vicinal railroads, feeders, etc., and to describe the developments and extensions of recent years, especially on the Continent of Europe, for I am well aware that the narrow gauge is systematically opposed on every side, and frequently by technical men of repute.

I deem it one of the most important aims of engineering to cultivate the construction of secondary railways, which, in consequence of low cost, are yet dividend earning with a minor traffic, and are on the other hand suitable to deal with traffic of gradual growth, or with traffic developed by extraordinary causes.

In my final conclusions I stated distinctly that for secondary (local

and vicinal) railroads, as well as for all roads of inferior importance, which subserve limited interests and accommodate principally local traffic, standard and a great variety of narrow gauges have been adopted. The latter have been chosen in just appreciation of their economic advantages in construction and operation. I also added that in certain cases the adoption of the standard gauge might prove desirable for secondary railroads; but that, as a general rule, the narrow gauge was the rational solution of the question of the simple and economical construction and operation of secondary lines, even for a not inconsiderable traffic, and that the narrow gauge was also to be recommended for main lines in countries with a presumably moderate traffic, and where the financial status necessitated the greatest possible economy, so that the invested capital might earn a good interest as quickly as possible.

If the whole argument of my paper is deemed by the gentlemen I named to be a collection of assertions, and to demonstrate nothing, I must state in reply that their protests are not calculated to throw light on the subject.

It is true that a standard-gauge line can be constructed with light superstructure and light rolling stock; but even in this case the cost of constructing and stocking will be higher, because more land must be acquired and a wider roadbed built, with a greater development in its establishment. The superstructure will cost more in consequence of the longer sleepers and increased width of crown of ballast, and of the increased width of the rolling stock, without attaining any compensating advantage, while in the event of a connection with any other standard-gauge line, the transfer of the rolling stock from the main road is impracticable in consequence of its greater weight.

My opponents' contention may be right, that a ton of narrow-gauge locomotive costs more than a ton of standard-gauge locomotive; but it is undoubtedly true that a narrow-gauge locomotive costs less than a standard-gauge locomotive, and, which is in favor of the narrow gauge, that a certain number of locomotives are needed to work a given number of trains. For example, a locomotive of the Saxon State narrow-gauge line (0.75 m. gauge) costs 21 376 marks, as against a standard-gauge locomotive of the Saxon State railways, which costs 44 902 marks.

Maintenance of the narrow-gauge locomotive..... 1 784.87 marks.
Maintenance of the standard-gauge locomotive ..... 2 695.24 "

In a serious question of the nature of this one, I treat as an ill-placed jest the remark that small men should be found to operate such light lines.

In point of fact, secondary railroads, on which the speed will depend upon the importance and extent of the traffic, can, without diminishing safety, be operated more simply and with a less numerous and experienced staff of employees. This alone constitutes an economy, without any references to the further advantages set forth in my paper. If proof be necessary in respect of saving in cost of construction, this may be obtained easily by consulting the surveys and estimates made for one and the same line on different gauges, to which I also referred, and thereby demonstrated that the cost of construction and width of gauge are inseparably connected. Nor have I in view, as Mr. Prout may think, merely the construction of a mill or plantation railroad; but public lines intended for passenger and goods traffic. I quoted, giving some particulars, several lines operating in various countries, which it is inferred that I selected on account of the favorable ratio of their working expenses to income, without giving any particulars of their traffic. Had I desired to give these particulars, I should have been forced to compile statistics, which would have exceeded the limits of a paper, and this would have been superfluous, for having quoted the sources from which my information was drawn, every one could procure the desired details for himself.

Mr. Foster Crowell's statement, that the narrow gauge has been demonstrated to be a practical failure in America, that some of the roads have been remodeled into standard-gauge railroads, and that others have been provided with a third rail for the standard gauge; further, that operating the standard-gauge roads had been much more profitable than operating the narrow gauge, and that the arguments for the narrow gauge at this time are ancient history, all go to show that either the narrow-gauge roads have been constructed in unsuitable cases or in ignorance of the conditions, and not in accordance with modern tested practice, in narrow-gauge construction, and, perhaps, that they have been operated as though they were standard-gauge main lines.

If all the defects of narrow-gauge roads were so uncontested, it were hardly conceivable that in America, during the last ten years, new narrow-gauge roads should have been constructed, though their average length be only twenty-three miles.

The reference also to Mr. C. Prieto Basave's report merely goes to show that in Mexico the narrow-gauge roads have been badly constructed, and not very well operated.

The communications in my paper are based on practical results, and are in no way the vague assertions which Messrs. Prout and Foster Crowell assume them to be. The results appeared to me, indeed, to be suited to throw light upon an important question. It may be gathered from the paper that narrow-gauge roads continue to extend in European countries in consequence of their higher economic advantages in point of construction and operation.

The governments of Prussia, Russia, France, Belgium and Austria have regulated the application of the narrow gauge by certain enactments, of which those in Prussia and Russia, issued as late as 1892, are worthy of special attention.

The resolutions of the International Railway Congress and of the International Permanent Tramway Union, which resolutions, therefore, may be deemed to be those of competent bodies, bear witness to the economic importance of the narrow gauge for secondary railroads.

The following resolutions, which could not be embodied in my paper, were passed in September last by the Congress of the International Permanent Tramway Union, held at Buda-Pesth:

"In consequence of the saving which can be effected in their construction and operation, narrow-gauge railroads are destined to form an economical and valuable adjunct in completing the existing network of railroads, and to influence the prosperous development of railroads of inferior order.

"Each of the three gauges in use up to the present time, 1 m., 0.75 m. and 0.60 m., has been found useful in practice under given conditions, and their application, therefore, is justified. The choice of gauge should, however, in each case follow the careful consideration of the conditions presented by detailed investigations of the existing and future probable requirements of traffic, due regard being given to local needs, the convenience of passengers, and the financial and other support available.

"In order to secure the earning of suitable profit on the capital invested in such lines, the limited aims of which are to be realized at low cost, due regard must be given to economical construction and simple cheap operation."

In conclusion, I should like to state that in Bosnia and Herzegovina a continuous network of narrow-gauge railroads, with 0.76 m.

gauge, and 609 km. in length, is in operation, which meets heavy military requirements, although the average cost of construction was 53 206 florins* per kilometer, in despite of the exceptionally heavy character of the country, and the rendering permanent a road laid temporarily in the first instance.

During the year 1891 the traffic of the Bosnia line per kilometer averaged 73 271 passengers and 65 411 tons, and the average gross receipts per kilometer, 4 350 florins. The working expenses amounted to 1 893 florins, and the capital earned a dividend of 4.6 per cent.

The Salzkammergut local railroads, 64 km. in length, and the Styrian local provincial railroads, 49 km. in length, were constructed in consequence of the satisfactory results of the Bosnian and Herzegovinian lines, with a corresponding gauge of 0.76 m. Having been in operation for one year only, no returns are yet available. This year 76 km. of local railroads have been under construction in Styria on the same gauge, and within the last few days the local railroad Ibsthal, 70 km. in length, with a gauge of 0.76 m., has been chartered.

In the Kingdom of Saxony the first narrow-gauge local railroad, with a 0.75 m. gauge, was built in 1881. At the present time there is a network of 17 narrow-gauge lines, 282.15 km. in length, equal to 10.54% of the whole of the Saxon railroads. The average cost of construction per kilometer of the standard gauge amounted to 289 498 marks; of the narrow-gauge lines, to 73 120 marks.

These facts alone, drawn from my native country, and within my own experience, ought to form an irrefragable argument that the employment of the narrow gauges, for secondary and local railways, as well as for extensive connections, with not unimportant traffic is both justifiable, suitable and profitable.

In any case the opinions expressed at the Congress by the two technical gentlemen in question will not in any way influence the movement in favor of the narrow gauge in Europe where the cry is becoming ever louder for cheap local railroads.

* Austrian currency.

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667.

(Vol. XXX.—December, 1893.)

RAILWAY SIGNALING.—DISCUSSION ON PAPER No. 622.*

By GEORGE R. HARDY.

GEORGE R. HARDY, M. Am. Soc. C. E.—It is worth noticing that this is a very exhaustive paper, and is so extended as to preclude a detailed discussion of its many points. The author delineates the various kinds of signals and the methods of using them in different countries. He mentions those in use here, but seems to have overlooked the Sykes system of block signaling.

We are interested to note the tendency to separate the considerations of the means used to actuate the signals from the engineering of operation. Invention has made splendid progress with the first part, but the scientific analysis of the second is still defective. This may be due to the natural conservatism which is encountered when engineers presume to offer to executive officers suggestions as to the business of operation. To a large degree the introduction of signaling becomes revolutionary.

* "Railway Signaling." By G. Kecker, Betriebs-Director, Imperial Railways of Metz, Germany. *Transactions*, Vol XXIX, p. 491.

We will not now attempt to describe or classify the many variant conceptions of the use of signals. Signaling is an element of the operating services, and in a twofold capacity may protect an obstructed track, or expedite the speed by its guarantee of a clear track.

We have seen in this country, contemporaneously with the development of signaling, the rapid strides of improvement of railway plant and devices. Signaling struggled slowly when we were banging our cars over the old stub switches, but advanced more rapidly when we changed to the high rail and planed points. Rearrangement of yards and terminals came with signal towers, enabling the same length of tracks to answer for increased number of train movements.

The author devotes considerable space to remarks on the subject of the colors used in signaling. Speaking of the German practice, we quote: "By this arrangement the locomotive engineer never passes a red signal." Again he notes the experiments of the Chappe Brothers, which showed the visibility of three kinds of lights, viz., white, red and green, was as 1, $\frac{1}{3}$, $\frac{1}{5}$. Again he says: "Movable glass blades or screens, especially if exposed to the weather, are easily broken, and should this occur it might happen * * * that an accident might result. * * * It seems undesirable to arrange signals in such a way that a red or green light might by accident be changed to white."

We therefore find the author has given three good reasons for some modification of the usual plan of colors for signals:

First.—The circumstance of an engine passing a red signal.

Second.—The existing inversion of the adaptability of the lights as regards their visibility.

Third.—The possible accidental changing of a colored signal to white, meaning all clear, when the reverse is the case.

It was mainly due to a careful consideration of the first reason that the system of signals used on the Boston and Albany Railroad was arranged. With regard to visibility of lights, it is safer to extend the warning of danger with the more perspicuous and use the one of lesser visibility for the all-clear signal; therefore, the green light has been tried on some railroads, and found best as an all-clear signal. Should the green screen or lens be accidently removed, the white light so uncovered would not be likely to cause an accident.

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TRANSMISSION OF POWER IN OPERATING CABLE RAILWAYS.—DISCUSSION ON PAPER No. 623.*

By A. BRYSON, DANIEL BONTECOU and ROBERT GILLHAM.

A. BRYSON, M. Am. Soc. C. E.—Mr. Gillham is to be congratulated on having given to the Society such an able and exhaustive paper upon a subject of such great engineering interest and financial importance. Had a description of the alignment in each case, however, been added, or the total number of degrees of curvature been placed in another column of the tables, with the ratios of diameters of curve pulleys and their journals, clearer analyses, and, possibly, general formulas applicable to nearly all cases might have been deduced.

It seems to the writer that exception may properly be taken to the "Average Horse-Power per Train," in Table No. 1, as being somewhat misleading, in that it is deduced from the net horse-power only, after deducting that necessary for operating all the machinery. This is not quite fair when comparing results with other systems of power-transmission for transportation purposes. All the power generated is used somewhere and must be paid for, and, as the work actually performed,

* "Transmission of Power in Operating Cable Railways." By Robert Gillham, M. Am. Soc. C. E. *Transactions*, Vol. XXIX, page 543.

with the entire cost of doing it, is the result which it is desirable to know, each unit of work must be charged, not only with the actual net power expended, but also with its proportion of the power consumed in working up to it. Were this view of the case taken in making up the last column in Table No. 1, the amounts would be increased about $2\frac{3}{4}$ times.

In the tests of carrying pulleys, which are most excellent and instructive, the result of comparing Nos. 2, 4, 5, Table No. 2, is that the horse-power consumed per 1 000 ft. of rope at 7.3 miles an hour varies as the weights of pulleys and as the ratios of their diameters.

When the Walker rings are used it would be desirable to know how much more tension is needed on the cable for a given service than with the solid drums. If the difference is great it might become a serious question on a line having long cables, considerable curvature, heavy grades, and heavy traffic, notwithstanding they overcome some of the very serious objections to solid drums where no provision is made for slip.

As to the increased power necessary for increased speeds. An investigation of Cables 1, 2 and 4, of Table No. 6—they being nearly of the same length and with little or no curvature—shows a coefficient of .03, and that the horse-power per linear foot of cable increases very nearly as V^2.

This, however, does not agree with the tests mentioned as having been made at the Fifty-fifth Street Power Station of the Chicago City Railway, where "it was found that, in order to drive the empty cables at 13.76 miles per hour, 300.6 H. P. was developed, while to drive them at 9.65 miles per hour only required 184 H. P."

In this case if the increment were as V^2, the horse-power for the higher speed, assuming that at the lower speed to be correct, would be 374.1 H. P. The aggregate length of these cables, however, is 59 700 ft.; whereas, in the other tests given in Table No. 6, the longest of the three considered is 24 300 ft. Can these tests properly be compared, and, if so, is this more favorable showing of the longer line due to its better condition and absence of curvature, or is there a factor of the increment proportional in some way to length and weight of cable and the driving machinery, due to and varying as V^2 atmospheric resistance of wheels, drums, etc.

From the Fifty-fifth Street Station the maximum tension on cables during operating hours, when travel was at the maximum, is given as

10 420 lbs., and the maximum load is in Table No. 10 stated to be 167 tons; hence, to pull one ton at the given speed, 13.76 miles an hour, 62.4 lbs. was applied. In the next case, from the Twenty-first Street Power Station, the tension was 11 425 lbs. and maximum load 924 tons, showing only 12.35 lbs. needed to pull one ton. Such marked difference may be due to various causes; but as no explanation is given, it is thought to be of sufficient importance to justify a request for further enlightenment.

It would also be interesting to study the practical results as given in the tests of power absorbed on curves, but as only the cable speed is stated, and no mention is made of the other necessary data, maximum tension on cable, and diameter of pulleys and journals, no calculations can be made.

It is to be hoped that Mr. Gillham will be able to supplement his valuable paper with the data suggested prior to its publication in the Society's *Transactions*.

DANIEL BONTECOU, M. Am. Soc. C. E.—There have been so few precise records made of the details of cable railway power transmission, that Mr. Gillham's tables form a valuable addition to the stock of current information.

It is not practicable, with certainty, to analyze the resistances of machinery and cables in great detail, but the friction of all the machinery with the cables off the drums may be assumed without material error, at 10% of the total average power required, or, say, 5 H. P. per unit of rope, and the power required by the unloaded cables can be determined with reasonable accuracy.

Table No. 5 of the paper seems to me somewhat misleading in purporting to show that under any probable conditions the brake action of the Cleveland friction clutches could be so much. It is evident from the conditions stated that the total of 802 H. P. includes the engine and line shaft friction 5 times and the friction of one clutch 12 times. While on the other hand it is difficult to understand why, if the total machinery and rope friction was actually 476 H. P., the total power with 64 cars on the line could have been as low as 509 H. P., plus resistance of rope drums.

A test made of the new plant of the Washington and Georgetown Company showed that the friction of three Weston-Capen clutches on the driving pinions amounted to 29 H. P.

The figures given in the tables for resistances of cables are rather higher than should be realized with good details and maintenance, with the exception of the main line of the Kansas City Cable Company which has 22-in. pulleys and a 7-mile speed; and it is interesting to note that the horse-power for the ropes of that company seems to vary about inversely as the diameter of the pulleys.

The figures given for the rope resistances of the Chicago City line, about 34 H. P. per mile of single and probably straight track, are especially excessive, the large friction in this case being possibly due to heavy and badly balanced pulleys, and in some degree to the speed.

In designing the Washington plants it was assumed that the resistances due to ropes on 14-in. pulleys, and at a speed of nine miles per hour, would be 7 H. P. per mile of straight single track (0.00132 H. P. per foot of rope) and 1 H. P. for 14° of single-track deflection. These figures proved to be 2½% under the truth as developed by indicator tests, and included friction due to all deflections of the ropes, other than those at the curves. These tests, in the case of the new plant which drives three ropes, were made by first indicating the total friction of machinery and cables, then indicating the friction with the various ropes thrown off the drums, but without throwing off the clutches, a method which probably gives more precise results than any other.

Mr. Gillham's figures seem to confirm the fact that the resistances of ropes increase with higher speeds, but in a slightly higher proportion than that of the speeds.

A table which I have prepared gives reliable details of cable railway work which may be of interest in adding to those already presented in the paper (see page 552).

The power per car as given by averages deduced from indicator cards is usually misleading in failing to throw any light on the maximum requirements.

This average for a standard four-wheel car and average load is about 2½ H. P.; but even in the latitude of Washington a resistance of at least 8 H. P. per car must be anticipated and in some way provided for, and, when questions of heavy grade are involved, it should be remembered, for instance, that a loaded car on a 10% grade calls for about 25 H. P. In this connection I would suggest that the determination

TABLE

Line.	Engine.	Drive.	Speed. Miles per hour.	Machine friction. Horse-power.	Rope friction. Horse-power.	Rope. Length.	Single track. Deflection Degrees.	Diameter pulleys.	Remarks.
Kansas City.									
Grand Ave. Ry. Co.—						All ropes.			Pulleys with c. i. spindles 1 in. diameter in lignum-vitæ bearings.
Walnut St. Line	32" × 48"	Indirect C. I. gear.	8.0	45	223	74 700'	1 071	12"	
Fifteenth St Line		Direct mort. gear.	9.25	51	305				
Westport Line			10.25	15	40				
Holmes St. Ry	24" × 48"		12.85	18.75	50	18 900'		14"	⅞-in. steel spindles—babbetted bearings.
Washington, D. C.									
W. & G. Ry. Co.—									
Seventh St. Line	20" and 36" × 48" c.	Direct mort. gear.	9	40	1	33 000'	40	14"	⅞-in. steel spindles—babbetted bearings.
Navy Yard Line	36" × 72"	Direct	9	73	104	31 556'	682	14"	⅞-in. steel spindles—babbetted bearings.
Navy Yard Auxiliary			6		19.5	3 949'	374	14"	⅞-in. steel spindles—babbetted bearings.
Georgetown Line		Rope-drive	9		80	23 588'	910	14"	⅞-in. steel spindles—babbetted bearings.
Fourteenth St. Line			9		95.5	27 817'	680	14"	⅞-in. steel spindles—babbetted bearings.

Note.—Machinery friction given for engine and main shaft only, except in case of 36" × 72" W. and G. engine, when it includes all machinery, with ropes off drums.

of the size of engines for a cable road demands very careful judgment in order to insure enough power when needed and to avoid running with an under load during a large portion of the time.

Recent practice seems to have settled on driving the drums directly from the main shaft and with 2-in. rope slings, although a number of plants have been installed on the Pacific Coast driven by a continuous rope. The freedom from noise, vibration, breakages due to sudden strains and back-lash, all of which have proved serious objections to gears, are very decided advantages on the side of the rope-drives, and may be considered as essential ones in a city power-house.

I think Mr. Gillham rests under a misconception in regard to priority in curve construction, and, in fairness to the group of ingenious men who worked out the details of the first San Francisco roads, will state that, while the Kansas City Cable Company's line was not operated until 1885, the Sutter Street Road, which was converted into a cable road in 1876, had two right-angle horizontal curves in which the main rope was run on 20-in. pulleys with details very similar in principle to those in common use now. And before 1884 the MacAllister Street main rope was operated around four horizontal curves of about 45° each. It would, however, probably be correct to say that the Kansas City case was the first application of Miller's duplicate rope system to a curved line.

I notice that Mr. Gillham states that the rings of the Walker drums of the Cleveland plant allow equalization of stress in the cable, and would be glad to know if we are to understand that that fact has been determined with precision in any way.

I have used the Walker drums, and believe, as do many others, that they probably have many advantages over a solid cast-iron drum. I know that the rings move relatively to each other under the conditions of actual work, and that I could not find that there was any appreciable wear on the rings of the Seventh Street plant at Washington after a year's use; but I have never been satisfied that the rings were so sensitive, and accommodated themselves to the strain so regularly as to equalize the rope strain to an appreciable degree. Of course this is purely an empirical matter, and any precise information would be of interest. If the friction on the seat of the rings under the usual conditions of lubrication is enough less than the friction of the rope in the grooves of the ring, to invariably cause the ring and not the

rope to slip under small variations of power, then the equalization of strain would occur and would be evidenced by absence of wear in the groove. This is the only kind of determination which occurs to me as practicable.

Better information about the relation to the resistance of the number of wraps on the drums, and also about the size of drums and the limit of operation with one drum only driven, is much to be desired.

A very interesting paper on "Cable Railway Propulsion," read by Mr. W. W. Hanscom before the Technical Society of the Pacific Coast, in 1884, analyzed the results of operation of the first seven San Francisco roads, and deduced the conclusion that their maximum possible efficiency with cars 1 000 ft. apart was 50 per cent. A comparison of the best of these lines with the best lines of recent construction indicates that the possible efficiency may now be placed at a higher percentage.

ROBERT GILLHAM, M. Am. Soc. C. E.—I regret that I am compelled to discuss or reply to discussions of the paper, "Transmission of Power in Operating Cable Railways," here in New York, for the reason that all the data relating to the subject are in my Kansas City office. I will, however, add a few explanations to what has already been written regarding the subject. I fully appreciate the fact that many additional items could have been incorporated in the paper that would have added much to its general interest and value; but, at the same time, for many reasons, it was desirable to limit the scope of the paper.

With reference to the suggestions made by Mr. Bryson, I may say that the degrees of curvature, diameter of curve pulleys and their journals, without complete details illustrating the design of curves, curve pulleys and their journals, would not be of as great value as might at first appear. The tables would certainly appear more complete with this information added, but there would still remain the necessity for explanations.

In a few cases on curves, the curve pulleys are removed and the cable conducted around large 12-ft. sheaves in vaults beneath the tracks. This method is resorted to for the purpose of prolonging the life of the cable, and also to reduce cable friction, and is introduced usually on level curves, also in curves having descending grades in direction of street-car traffic, where the ordinary street traffic will admit.

The cars pass the curves in the first instance by momentum, and in the second by gravity. Two cases of single-gravity curves may be found on the Washington Street line, Kansas City, and one double-track momentum curve on the West Denver line, Denver, Colo. In the last case here given, cars release the cable on entry to curve, and pass around the same by the acquired momentum of cars. The curve pulleys, as has been stated, are entirely removed, and the cable conducted around two large 12-ft. sheaves placed below the street, close to the intersection of tangents of each track.

The Denver curve pulleys were designed interchangeable, and are in all respects alike.

TABLE A.

CURVE PULLEYS.

NAME OF ROAD.	Diameter of pulleys.	Weight of pulley.	Diameter of journal.	REMARKS.
	Inches.	Pounds.	Inches.	
Denver City Cable Railway...	15	108	$1\frac{1}{16}$	Diameters are given from bottom of groove.
Cleveland City Cable Railway.	39	337	$2\frac{1}{4}$	
Kansas City Cable Railway...	34	415	$1\frac{3}{16}$	Main Line.
	34	415	$1\frac{3}{16}$	Independence Avenue.
	23	240	$1\frac{3}{16}$	Summit Street.
	34	415	$1\frac{3}{16}$	East 9th Street.

The average horse-power given in Table No. 1 relates entirely to the power required to move trains above and in addition to that required for machinery and cable friction, and was arranged in this form in order to separate the power-absorbing elements in cable operation. In the use of Walker rings on driving drums, it does not appear that very much additional, if any, tension weight is necessary, compared with solid driving drums, conditions being equal.

The horse-power per linear foot of cable as given in Table No. 6 for Cables Nos. 1, 2 and 4 increases, it is true, very nearly as V^2, but this fact should not be made an absolute basis of comparison with power tests for cable friction on other lines, for the reason that local line conditions vary greatly and are very rarely alike save in the matter of cable length. Cable No. 1, Table No. 6, has a slight curve, the degrees I cannot now recall; but this curve requires six curve pulleys. Again, on one portion of this line, the route passes through an unusual depression, making it almost necessary to use depression pulleys.

Cable No. 2, Table No. 6, has also a slight curve, requiring four curve pulleys, and in addition operates the auxiliary machinery, which in turn drives the Water Street loop.

Cable No. 4, Table No. 6, has no curves, but is required to pass from power station to front vault, around two sheaves; thence to Kirtland Street, around two sheaves; thence through a blind conduit, about ¼ mile, to the Payne Avenue line, where it again passes around two vault sheaves. In this case we have the cable passing half around six extra sheaves not found necessary in the other cables.

Thus the statement in remarks of Table No. 6 to the effect that there were "practically no curves" is a little misleading when the data given is used in comparisons similar to that made by Mr. Bryson. The conditions associated with the operation of each of the above cables vary greatly.

The tests in Table No. 6 cannot be properly compared with the test at the Fifty-fifth Street power station, Chicago City Railway, for the reason that the conditions are widely different. The cables tested at Fifty-fifth Street are straight, having no curves or depressions of any kind, and only two vault sheaves each, except the Hyde Park loop on Fifty-fifth Street rope.

With regard to the difference in power required per ton of load as developed in the Chicago tests, I have not the data at hand to make further statements on this question.

Mr. Bontecou, in discussing the paper, seems unable to understand why the brake action in the Cleveland clutch test should have been so great. The subject-matter on page 556 (Vol. XXIX) of the paper describes the causes of this excessive brake action, but perhaps the statement is not quite as clear as it should have been. I will, therefore, make a further explanation of this test, that it may appear clearer and be better understood. Mr. Bontecou's test of brake action of Weston-Capen clutches in Washington agrees quite closely with similar tests made by the writer with clutches of this design that were in ordinarily good adjustment and repair, but the point in the Cleveland case is one that embraces the question of design in important details, which details are radically different from those involved in the Washington, Denver or Kansas City clutches.

The Cleveland clutches were designed by the manufacturer, and placed on the machinery as Weston-Capen clutches. The fact is, they

fully covered the principle upon which this clutch is designed, except in the method of forcing the friction plates together. Instead of using the usual toggle principle, for the purpose of throwing the circular steel plates, in the sleeve of the clutch pinion, in contact with the circular steel plates, attached to and which rotate with the main shaft, the wedge principle was used, differing very materially from the well-known toggle. The use of a movable wedge for the purpose of forcing the clutch plates together resulted, in this case, in reducing the horizontal movement of the movable plates more than one-half. In the clutch in question, the horizontal movement was entirely too slight, and, with the lost motion in the clutch lever and connections, the clutch plates were more frequently left in contact with each other than out of contact, even though the clutch lever was thrown entirely out.

On more than one occasion when the clutch lever was thrown out entirely, and the plates should have been out of contact with each other, they remained in contact sufficiently to continue propelling the cable. It was this condition of affairs that was determined in the test indicated by Table No. 5 in the original paper, and which fully accounts for the brake action of 292.47 H. P.

The details in the clutches were afterwards changed, additional horizontal movement of plates secured, resulting in minimum clutch friction, and the correction of the difficulty noted.

The results given in the paper, relating to and indicating the power required to propel cables, may, as Mr. Bontecou suggests, seem in some cases a little high, which is not chargeable to defective designs in road machinery, but may, to a great extent, be due to varying conditions and indifferent maintenance of road machinery. None of the railways where tests were made were on dress parade.

Mr. Bontecou has submitted very valuable and interesting data relating to other cable railways, for which it is claimed most excellent results are secured, and this leads him to remark, with reference to the power required to overcome cable friction on the railways reported in the original paper, that the cable friction "is rather higher than should be realized with good details and maintenance."

Comparing the data presented by Mr. Bontecou from cable railways with which he, as designing engineer, was associated, with those referred to in the original paper, possesses interest.

TABLE B.

ILLUSTRATING THE AVERAGE HORSE-POWER REQUIRED PER LINEAR FOOT TO OVERCOME CABLE FRICTION, THE AVERAGE SPEED OF CABLES, AND THE TOTAL LENGTHS OF CABLES, IN THE RAILWAYS IN THE VARIOUS CITIES IN WHICH TESTS HAVE BEEN MADE (NOT INCLUDING MACHINE FRICTION).

LOCATION OF RAILWAYS.	Average rope friction, horse-power per linear foot.	Average speed, miles per hour.	Total cable length in feet on lines tested.	REMARKS.
Kansas City, Mo.— Walnut Street Line.....(B.) Fifteenth Street Line....(B.) Westport Street Line.....(B.)	.0070	9.16	74 700	This is the highest cable friction reported. For degrees of curvature, see table by Mr. Bontecou
All lines, Grand Avenue System, Kansas City.....(B.)	.0066	10.08	93 600	
All lines, Washington, D. C.(B.)	.0028	8.5	119 910	
Seventh Street, Washington D. C.....(B.)	.00124	9.0	33 000	Seventh Street cable is most favorably located, and has no right-angle curves, and is practically straight.
All lines, Kansas City Cable Railway.....(G.)	.0031	8.7	94 132	
Main Line, Kansas City Cable Railway .....(G.)	.0017	7.3	22 000	Two double right-angle curves
Washington Street Line, Kansas City Cable Railway...(G.)	.0029	12.0	23 759	One double and one single right-angle curve; one single gravity curve.
All lines, Cleveland, O.....(G.)	.0031	10.8	105 400	Five double right-angle curves.
West Payne Avenue, Cleveland, O.....(G.)	.0023	12.0	24 050	No curves.
All lines, Denver, Colo.....(G.)	.0036	10.0	155 617	Five double right-angle: two, 45°; one, 30°; one, 20°; one, 25°. One double momentum curve.
All lines, Chicago, Ill.....(G.)	.0059	12.1	112 930	

NOTE.—The lines marked with "B" are from Mr. Bontecou's table, and those marked "G" from Mr. Gillham's tables. The speed for Washington Street cable was noted in original tables as 8 miles per hour; it should have been 12 miles.

I am very pleased to accept the correction made by Mr. Bontecou, with reference to the date and place where main cables were first operated around right-angle curves. The San Francisco engineers have not received the full share of credit due them, and I regret that this error occurred in the paper.

I should have stated that the Walker rings "tend" to equalize the stress on the rope in passing around the driving drums, as I did not intend to make the broad statement that the rings "equalize the stress on the rope." The fact that the rings usually change their relative positions to each other indicates the absence of rope slip, and the absence of wear in grooves of rings tends to indicate equalization of stress.

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669.

(Vol. XXX.—December, 1893.)

THE CONTINUOUS SUPERSTRUCTURE OF THE MEMPHIS BRIDGE.—DISCUSSION ON PAPER No. 624.*

By GEORGE H. THOMSON, HENRY GOLDMARK, Sir BENJAMIN BAKER, ROBERT MOORE, CHARLES MACDONALD, GEORGE S. MORISON and ALFRED D. OTTEWELL.

GEORGE H. THOMSON, M. Am. Soc. C. E.—The author calls attention to a matter which is often overlooked in competitive design, that of "rigidity" of structure. There is in the railroad truss bridge specification generally a lack of provision for rigidity, probably on account of the lack of a full and complete formulation of a theory regarding rigidity of structure, or, as I term it, "structural motion." I regret very much that Mr. Morison has not laid before us his ideas regarding "structural motion." It would seem that at present our competitive designs for railroad bridges, constructed by the usual specifications, are very defective; there is no regard for "structural motion" whatever. In recent designs for railroad bridges I generally design with a provision for "structural motion." While truss bridges for railroads

*"The Continuous Superstructure of the Memphis Bridge." By George S. Morison, M. Am. Soc. C. E. *Transactions*, Vol. XXIX, page 573.

erected in the State of New York must fulfill certain requirements of the railroad commission, so that all parts of structures must be within certain limits laid down by that commission, there is no objection to making some of these parts heavier to provide for "structural motion." I would like to have Mr. Morison say something about this subject.

WM. METCALF, Pres. Am. Soc. C. E.—Are there any further remarks? It is hoped that members will at least ask questions and start up some kind of a discussion of these papers which the authors have taken so much trouble to present.

Mr. THOMSON.—Mr. Morison is very willing, but he wants some of us to lead him out. He could first define what is meant by "structural motion," or, as he might term it, "vibration," a word which has a different meaning in different countries, but taking the ordinary term, "rigidity," as used by engineers, I think if he would give us five minutes on that subject we would all appreciate it. He says here, "it is possible to design a structure in which no metal under any ordinary supposition will be overstrained, and yet without such overstrain vibrations can exist which would be utterly inadmissible." I think some of us could design a structure that would meet current requirements, but that would be so full of "vibration" that it would be merely a question of a decade or two as to its endurance. I know a bridge of 150-ft. span that has been visibly overstrained in one year, and another of 125-ft. span that did not withstand it so long. The use of steel with punched holes may have something to do with the cause of failure of these bridges, but the bridges were too full of motion. It would seem to me that if these structures have much of motion, it does not make much difference whether the iron is sustaining 6 000 or 8 000 to 10 000 lbs. per square inch, they will not endure; but if the structure has "rigidity," a mere matter of 15 000 to 20 000 lbs. per square inch will not make so much difference; it may endure for years.

HENRY GOLDMARK, M. Am. Soc. C. E.—Having witnessed the tests to which the Memphis Bridge was subjected at its formal opening, I am glad to bear witness to the remarkable rigidity manifested by this great structure.

Considering the fact that two of the spans are of cantilever construction, the deflections under the heavy test train were very moderate, indicating excellent workmanship, with very little play in the connections of the different parts.

There was also only a slight vibration in any of the separate members, even when the train moved over the bridge at a speed of 30 miles per hour. Under these conditions, there can be no doubt that the material in each member is utilized to the best advantage, and for considerable lengths of span the American system of pin connection fully maintains its position.

Having personally examined, in the field, during the past 10 years, many hundreds of railroad bridges, I have had ample proof that for bridges of more moderate span our ordinary methods of construction have, in the past, been very faulty. The light pin bridges, universal a decade ago, with suspended floor systems and pin-jointed lateral and sway rods, have not proved equal to the demands made upon them.

It is true that train-loads have been much increased, but even under light loads I have found the wear of the loose-jointed parts to be very excessive. In the floor system, riveted attachments have, of late, become almost universal, and it is only a question of a few years before the connections of the truss members will be made by means of rivets in railroad bridges under 175 ft. in length. For lengths of 100 to 115 ft., this practice is even now quite general, and I believe with excellent results.

I have built several spans of 120 ft., with riveted joints, which do not deflect over $\frac{1}{4}$ in. under 50-ton engines, and are almost free from vibration in any member. I am quite sure that this is a better result than is usually obtained in through pin-connected spans.

While the calculation of the strains in lattice trusses is apparently less correct and certain than where pins are used, there can, I think, be little doubt that, for short, and, consequently, light, bridges, the "strain sheet" does not, by any means, fully indicate the work which the metal has to do.

Where experience points so clearly as it does in this matter, it is very important to revise our views on this exceedingly practical subject.

Sir Benjamin Baker, Vice-President M. I. C. E.—Engineers understand that the strain sheet is not always a guide as to the effect of the vibratory strains on different parts of the bridge. I have had an opportunity of studying that in some detail during the last year, as I was called upon to rebuild a great many wrought-iron bridges which had been in existence about 40 years, and in pulling down the old bridges it was possible to see where the work really suffered from undue

stress. I found appearances of greatest wear where nobody would have anticipated if guided by the strain sheet alone. Thus the attachment of the trough flooring to the webs of the main girders is a part that is liable to suffer. In the calculations it is usually assumed that the trough flooring simply rests on the bottom of the flange. It is found best, however, to provide for what you may call the contrary flexure at the connection of the floor and girder and make a liberal allowance for it in rivet area. I have seen web plates entirely cut through with the continual wriggling at that point. The members of a bridge are often subject to secondary stresses reaching the limit of elasticity, and wear and tear occurs, although the calculated strains would be much lower than would account for the facts observed.

The loosening of rivets, also, in certain places is another defect observed in old bridges, and I found that to avoid the same, different attachments and riveting to those indicated by calculations are advisable in many cases.

Then there is a very important point which of course is habitually ignored in all calculations, that is, the initial strains which you get in bridge members, according to the form of cross-section. You straighten cold entire plates and bars, and in doing that I have found, by cutting the parts to pieces and seeing the changes which follow relief of internal stress, that in many cases you get varying stresses throughout the member quite up to the elastic limit, and I believe that in many cases so-called mysterious fracture arises from this, because, while you may nominally have 10 000 lbs. per square inch, you have really got stresses running from perhaps 20 000 to 25 000 lbs. per square inch during the passage of a train on portions of the cross-section.

I have in some cases seen evidences of a fracture beginning in the middle thickness of the metal quite out of sight, and constituting, therefore, a perfectly inexplicable failure, as bit by bit, perhaps a thousandth of an inch at a time, the fracture would grow until it extended through the whole section of the bar.

ROBERT MOORE, M. Am. Soc. C. E.—There is one thing in the design of the Memphis Bridge which appears to me to be of very special merit; that is, the design of the rollers which are placed under the span. This is one of the earliest, if not the earliest, structures in this country in which rollers of that design have been adopted. It is a design which ought to be very much more generally adopted than it

has been. It is probably within the experience of many members who have had occasion to observe the action of existing structures, of old structures, in which corrosion has begun and in which the accumulation of dirt about the rollers has taken place, that the small rollers usually placed under bridge spans do not roll. They become fast and bring upon the masonry and the structure itself stresses which are very great. I have recently had occasion to notice a case of this kind where the refusal of the rollers under two heavy spans has initiated a separation of the stones of the coping. I think that engineers generally will do well to take notice of this fact and provide for it very much as Mr. Morison has done by using sections of cylinders of larger diameter.

CHARLES MACDONALD, M. Am. Soc. C. E.—There is a question involved in this bridge which is of especial interest to the manufacturer, but which should also receive the attentive consideration of designers of long-span bridges. I refer to the difficulty of handling the cumbersome masses which are required for completing individual members or sections of the trusses. In this regard the Memphis Bridge would appear to have reached, if it has not exceeded, the limit of span in which the purely pin-connected method of construction is available. Take, for example, a section of bottom chord at the end panels. This is designed to resist tension and compression. It is composed of two vertical members connected by horizontal latticing above and below. Now, no matter how carefully the work of assembling and fitting may be done in the shops, there comes a difficulty, in transporting the completed member to the bridge site and erecting it in place, which is inseparable from the design.

In turning over such heavy masses distortion is almost certain to result. Pin holes which have been bored perfectly fair and at right angles to the vertical sides will be found out of line when the time comes to drive the erecting pins, owing to the impracticability of fixing such heavy masses by lattice plates.

Other instances of a similar character might be given, but this will suffice to call attention to the subject, an attentive consideration of which may lead to the conclusion that a combination of the European practice of riveting with the pin-connected method familiar in the United States will be found to be the true line of development for long spans.

GEORGE S. MORISON, M. Am. Soc. C. E.—The principal feature which has been brought out in this discussion has been the question of rigidity. There are two sources of motion in a bridge under strain, one perfectly legitimate, and one which should be avoided in every possible way. The legitimate source of motion is the change of length of metal due to strain. The illegitimate source is the lost motion which occurs in details, and I believe that more harm is done to bridges by vibration due to this lost motion than comes from every other source. Two or three years ago a bridge across the Mississippi River at Burlington, which would now be condemned absolutely for its details, but which was fairly considered a good design at the time it was made, was taken down. It had cast-iron top chords and post feet, but the only place where abnormal wear was shown was on the pins near the ends where the counters, which theoretically should not have existed, took hold of the pins; there the wear was very great. It was with a view to avoid lost motion in details that some of the heavy details of the Memphis Bridge, described in this paper, were introduced, and I believe that any one who has been on that bridge during the passage of a train will recognize that it is about as stiff cantilever construction as can be found. Of course it is not as stiff as a very much larger structure could be made, but any one who will examine it will recognize its rigidity as compared with other bridges of the same length of span and general dimensions.

There is one point which was suggested by Sir Benjamin Baker when he referred to strains existing in metal in positions where it could not be seen. Some years ago I condemned a large portion of the pins of a bridge for piping, and it occurred to me that the conditions that produced piping in some pins produced a strain nearly as bad as piping in others. Since that time I have adopted the plan of boring all pins through the center. There is no real difficulty in doing it, and it has at times shown a condition of the metal in the interior of of those pins which made me glad that I had required it. It is valuable, both as a means of detecting flaws which could not otherwise be found and as removing the condition of internal strain which has produced those flaws and which may even produce fracture; it is precisely analogous to the approved practice of boring steamship shafts. In a bridge which I am now building, the entire set of pins forged at one shop, and which were forged under too light a hammer, were rejected

for piping; it was necessary to have them forged at another shop which used a heavier hammer; the new pins showed no defects.

ALFRED D. OTTEWELL, M. Am. Soc. C. E.—In examining the details of this bridge one cannot fail to be impressed with the marked improvement in bridge building which has taken place in this country within the past ten or twenty years.

Ten years ago the European engineer visiting this country could justly criticise the frailty of American bridges, the vibration, the tremor, the rattle of the rods, etc. In the present example, however, the most fastidious critic would be pleased, for the design shows a liberal use of material, and that the efficiency of the details claimed the most attention, rather than economy in material or labor.

Looking at the general plans of this bridge, the question arises, how much, if at all, did this general arrangement of spans and piers differ from the strictly economical arrangement of spans and piers? As this is probably a hard question to answer, I will put it another way. If Mr. Morison had been at liberty to select his own length of spans, could he not have saved considerable money by using shorter and fixed spans for the bridge? My own experience—an experience very much more limited than that of Mr. Morison—makes it a matter of surprise to me that the cost of substructure in this bridge exceeded the cost of superstructure, and raises the question: was there anything in the nature of the bed of the river that made sinking the piers more costly than would be at first supposed?

There seems to be a lack of unanimity among engineers as to what is the most economical length of suspended span compared with the full span. In the present example the suspended span is $\frac{451.66}{790.42} = .57$ of the full span; in the Forth Bridge it is $\frac{350}{1710} = .205$; in Mr. MacLeod's bridge over the Kentucky River, L. S. R. R., it is $\frac{260}{551} = .47$; in Mr. Buck's Verrugas viaduct, $\frac{105}{260} = .405$; in the Poughkeepsie Bridge, $\frac{212}{546} = .39$; in the Sukkur Bridge, $\frac{200}{820} = .244$; in the Red Rock Bridge, $\frac{330}{660} = .5$; in Mr. C. C. Schneider's Frazer River Bridge, $\frac{105}{315} = .33$; Niagara Falls Cantilever Bridge, $\frac{120}{495} = .242$; in the Kentucky and Indiana Railroad Bridge, $\frac{160}{480} = .33$; in the proposed Channel Bridge, $\frac{125}{500} = .25$. Short

or long suspended spans seem to depend upon the unimportance or importance of deflection in the bridge. According to this principle a highway bridge may have a shorter suspended span than a railroad span of the same length; and the above ratio should be greater for short spans than for long spans for both railway and highway bridges.

It is interesting to note that the depths of spans in this bridge show a marked tendency towards the European practice of shallow depths.

The use of bulb angles in lateral struts is a decided improvement over the I form, whether the latter is rolled or built up of ordinary angle irons. The bulb angles at present on the market are too heavy for use in most bridges for this purpose. It appears to me that if the rolling mills would roll a series of smaller sections of this shape they would find a ready market.

Mr. Morison's explanation of the method used in ascertaining the sizes of pins is very satisfactory as far as it goes. It would be interesting, however, to know exactly how the size of a particular pin was determined. The customary process is both long, tedious, and unsatisfactory when completed, so that if Mr. Morison has a shorter and simpler method, the profession, I am sure, will be glad to know it.

The advocates for single intersection must be disappointed in the fact, that this important bridge was built on the double intersection plan. I have for some time thought we shall in long spans revert to the single intersection form of truss employed by Mr. Albert Fink for the 400-ft. channel span of the Louisville bridge. This bridge, it will be remembered, has a Warren primary truss of long panels, each subdivided into four shorter panels, to carry the floor and stiffen the upper chord. This form of truss has the advantages attributable to long panels, definite strains, duplication of parts, concentration of strains, fewer members. Whether these advantages are counteracted by disadvantages remains to be seen.

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670.

(Vol. XXX.—December, 1893.)

BRIDGE SUBSTRUCTURE AND FOUNDATIONS IN NOVA SCOTIA.—DISCUSSION ON PAPER No. 625.*

By K. SUTHERLAND, F. W. W. DOANE, W. R. BUTLER, E. GILPIN, P. S. ARCHIBALD, H. S. POOLE and MARTIN MURPHY.

K. SUTHERLAND.—Dr. Murphy is to be congratulated on the success that has attended his constructions in concrete in Nova Scotia, and I think this is due largely to the interest he has taken, as well as the time he has given in personal supervision, even to the most minute details of the several structures he had in hand.

The widely divergent uses to which concrete can be applied with satisfactory results obtained in practice on some of the railways here, and the interesting papers on that subject read by Dr. Murphy before the Canadian Society at Montreal, has invested the details of bridge substructure and foundations with an interest second only to its importance.

I notice that the author has instanced the concreting of two bridges on the line of the Windsor and Annapolis Railway, namely, the Avon

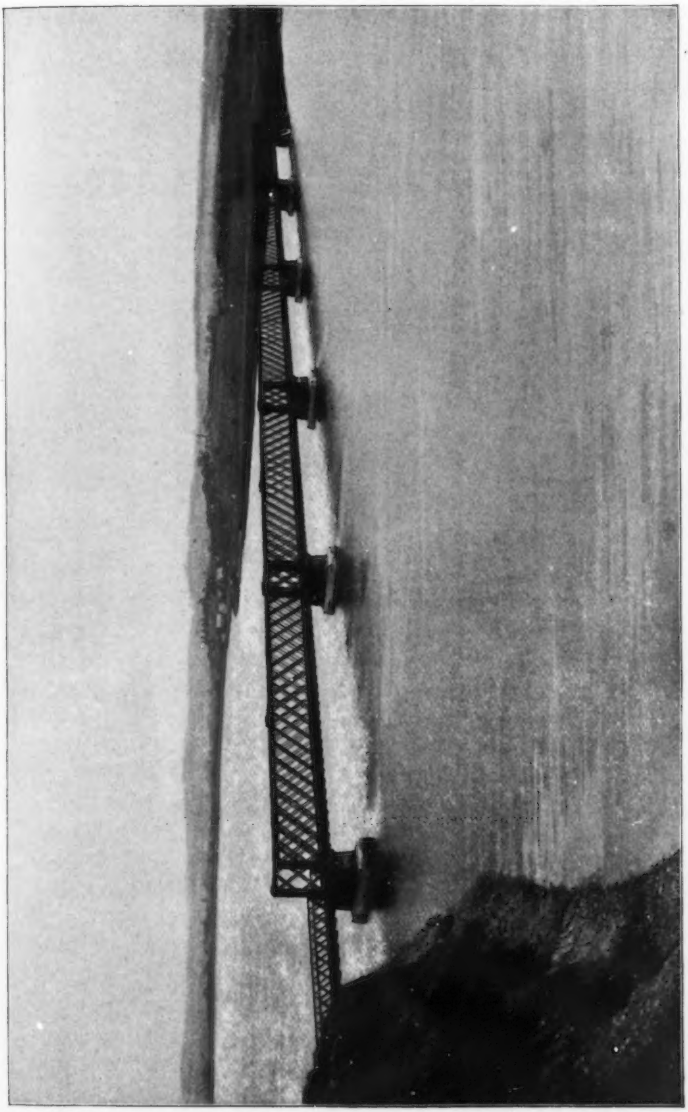
* "Bridge Substructure and Foundations in Nova Scotia." By Martin Murphy, M. Can. Soc. C. E. *Transactions*, Vol. XXIX, page 620.

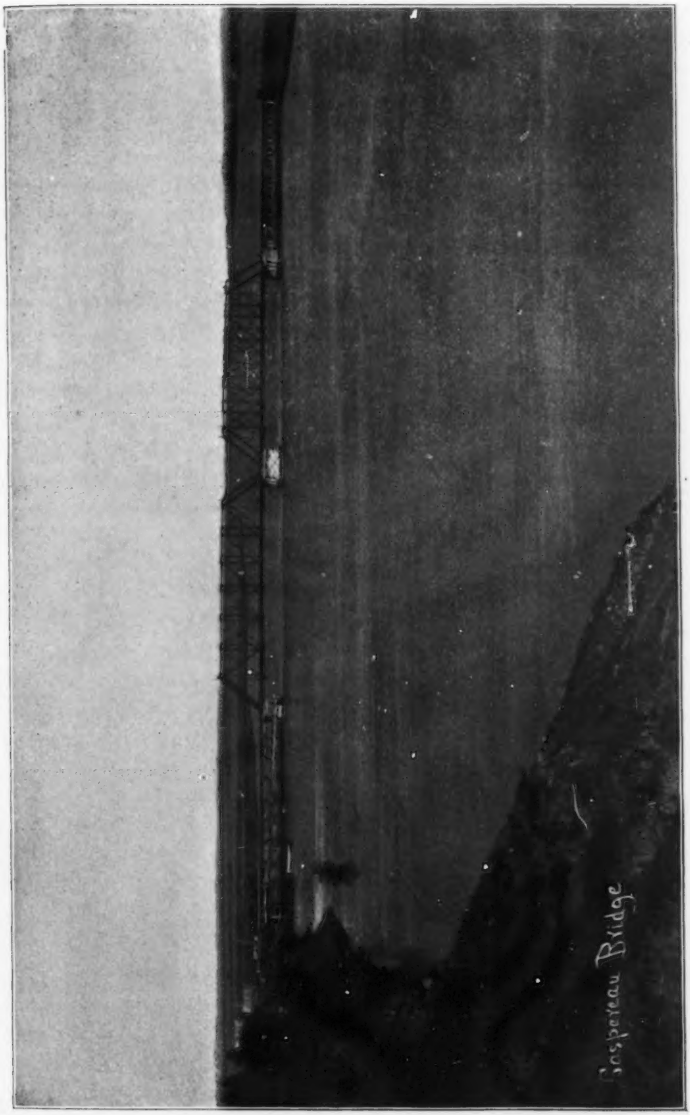
River Bridge, over the Avon, and the Gaspereaux River Bridge, over the Gaspereaux.

Avon River Bridge.—Of the eight piers in this structure, five were concreted by commencing on the outside of the ashlar masonry and incasing them with a matrix to 3 ft. above high water, the outside of which was protected by cribbing of 10 x 10 spruce timber, for the purpose of holding the matrix in place while being deposited.

The estuary of the Avon at this point having a tidal rise of about 28 ft., and a current of six miles an hour, the work of depositing the foundations was attended with some difficulty in keeping the material from being washed out at every influx and ebb of the tide. This was, however, overcome by the knowledge we had gained in putting in our foundations, so that we were enabled in a very few days to put a belt of concrete around the piers of from 1 to 1½ ft. every 24 hours. The proportion of material forming the whole body of concrete was 1 bbl. of White's Portland cement to 1½ bbls. of clean sand, 1 bbl. of clean gravel, and 4 of common field stone. These stones weighed from 8 to 20 lbs., and were all dropped or placed by hand, so that as far as practicable no one stone would touch its fellow. The matrix was delivered *in situ* from top of pier, falling 10 to 30 ft., so that very little, if any, ramming was necessary. The thickness of belt of concrete at foundation was 2½ ft., finishing at 1 ft. 4 ins. This work has now been on probation for over four years, and has so far completely filled the object for which it was erected, namely, the prevention of further disintegration of the bridge piers. This belt to-day clings as closely to the ashlar as on the last day of its completion, without a "thread-rent" or displacement to be noticed; in fact, a monolith. The cost was $7 25 per cubic yard. A view of this bridge is given on Plate I.

Gaspereaux Bridge.—This structure consisted of three piers only, and the object of supplying concrete for rebuilding was widely different from that of the Avon River, but the success which had attended the repairs to the latter warranted us in applying the same system, so far as the material of which it was composed was concerned, in the projected rebuilding of the Gaspereaux. The three piers were of the ordinary so-called trestle bents resting on piles capped and interbraced with each other, these piles standing 12 ft. above the surface at low water, with probably 10 ft. below the surface, into the hard river mud. This interbraced piling had become crippled and bent in toward the




Saskatchewan Bridge

middle of the river, so that the time had come for reconstruction, either with ashlar masonry or with concrete, as above noted.

The superstructure consisted of two American pin-connected truss iron girders; lower chords of eye-bars; each span being 145 ft. A view of this bridge is given on Plate II.

To build the piers of ashlar would have necessitated the construction of solid false works, to enable us to keep our train service intact, so that the idea of concrete piers, which would obviate the necessity of any false works, and, therefore, the conclusion to build concrete piers was at once, I believe, a judicious and happy movement in the direction of economy as well as facility of construction. The result has justified this. We commenced operations by excavating about 8 ft. below the surface, 6 ft. under low water, until we found hard clay with an admixture of gravel, cutting out only about 6 ft. of plan section at one time, placing therein 3 ft. of field stones, grouting the same with 1 to 1½ of cement and sand, until the whole foundation was completed. We then proceeded with the same proportions of concrete material as in the case of the Avon River Bridge, cutting out nearly half of the timber in bents and filling as the work progressed; completing the piers on top at 8 ft., excepting in the case of the center pier, at 10 ft., which held the ends of both trusses. The tops of all the piers were capped with large and well-dressed hard free stone, chamfered around the edges, and giving the whole a finished appearance. During construction the concrete was kept in place by a wooden framework of 6 x 3 spruce, on the inside of which 1½-in. plank was fastened. The Gaspereaux, although not so wide as the Avon, has 4 ft. more tide, and the same speed in its current. We had no difficulty in maintaining all our concrete in position as deposited, no doubt owing to our having passed the experimental stage at the Avon River Bridge, in placing concrete in the tidal waters of the bay of Fundy.

Mr. F. W. W. Doane.—In discussing Dr. Murphy's interesting and valuable paper, I can testify to the satisfactory results that have attended the use of concrete in Nova Scotia, as I am familiar with most of the concrete work done in the Province.

It is rather surprising that engineers are so conservative in their practice, and that the adoption of concrete as a building material is not more general, since the discovery of the process is by no means recent. One urgent reason for its adoption in the city of Halifax

is the difficulty in connection with the employment of skilled labor.

In work such as Dr. Murphy describes monolithic massiveness is of the first importance, as the resistance to blows from drift ice, logs and rafts, and the power to withstand the freezing and thawing of a Nova Scotia winter, cannot be obtained in quarried stone. The experience so far has not shown any failure from the action of frost on concrete structures in our climate, which is more severe than in the Upper Provinces, in consequence of the rapid and frequent changes in the temperature.

The draw pier of the "Victoria Bridge" referred to by Dr. Murphy has been an unquestionable success. This work was done where there is a very rapid current, and consequently the blows from drift-ice, logs, etc., are very heavy, and the destructive effects of freezing and thawing would be more noticeable in consequence of the great rise and fall of the tides. The drift-ice and other floating material strike as impotently against the pier as if it were a lump of lead, and the freezing has no effect upon it whatever. Compared with the conduct of masonry under similar circumstances, concrete is far cheaper, even if the first cost were more than that of masonry, instead of less.

It is of course important that great care should be used in the selection of material and the method of compounding, as the quality of concrete depends on the material used and the skill in mixing. It is also important that concrete work should be done before cold weather, so that the process of induration shall be sufficiently advanced to prevent the surface from cleaving and disintegrating. Uniformity in the quality of cement is also important.

The construction of concrete work was at first unpopular in this Province. It was thought expensive and was opposed by the public, although it was not exactly an experiment. It was undertaken hesitatingly at first; but it is now employed in the construction of all classes of work.

The building stone in Nova Scotia is generally too far away to compete successfully with concrete in cost. In Halifax, for the reason already given, namely, "the difficulty in controlling skilled labor," it was found to be much more economical and satisfactory to build sewers, sidewalks and catchpits of concrete instead of brick. The sewers are constructed of concrete blocks molded to the proper form

and allowed to set for some time before being used. They are laid by ordinary workmen, who are paid less than half the wages demanded by skilled workmen, who must be employed to construct brick sewers.

Catchpits built of concrete are perfectly water-tight and easily cleaned, and the cost is much less than those built of brick, or the recent invention of cast iron. They are provided with a concrete cover, or, in places where the traffic is very heavy, a granite curb is set in the face and a cast-iron cover used.

W. R. Butler, Assoc. M. Inst. C. E.—Doctor Murphy's paper will command the careful and interested attention of members of the Congress as exhibiting methods bold and novel in character, very successfully adapted to meet cases of somewhat peculiar difficulty. That the several problems presented have been solved by economical methods, but at no sacrifice of permanence or stability, both as to the general designs and also as to the execution of their details, the writer believes will be generally admitted.

Concrete has in many instances proved its superiority to masonry construction in the waters of our tidal rivers, especially where such repeated, rapid and extreme fluctuations of level obtain as in the tidal waters of the bay of Fundy.

The railway bridge across the Avon at this place (Windsor), referred to by Dr. Murphy is a notable example of the deteriorating effect of such influences upon heavy masonry, with which the writer is very familiar. At one hour of the day the external face may be subjected to a water pressure due to a head of from 30 to 50 ft., and a few hours later the same face may be exposed to atmospheric influence; at half tide the rate of rise and fall is approximately 1 ft. in from five to seven minutes; the effect of this, in a temperature far below the freezing point, together with blows from masses of floating ice of 50 tons upwards, may be imagined, the current running, as it often does, some 5 or 6 miles an hour. These masonry piers, in spite of constant watching and repairs, have proved utterly unable to withstand the deteriorating influences, and the treatment referred to by Dr. Murphy has been resorted to.

The design of the highway bridge discussed in the paper and represented in some of the details in Plate I, seems to fulfill all the requirements of the locality—the writer has seen its stability very severely tested. On one occasion by the thrust of a compact body of heavy

ice, filling the estuary below for some miles from bank to bank, and steadily advancing up stream, impelled by wind and tide, each pair of cylinders was cutting its lane through the ice floe, which was more or less cemented together by half frozen slurry from a heavy snow storm, to the accompaniment of much groaning and crushing of ice-cakes and vibration of bracings. The bridge, however, has stood this, and many like tests, unimpaired. As to floating masses of heavy ice or such like objects, and their damaging effects upon a bridge pier, the writer is tempted to advance the observation that it will be less upon a pier presenting its full breadth as a face at right angles to the direction of the current, than upon a similar pier built with a cut-water; at any rate, when the current is a swift one, the floating body is diverted from its course further up stream, the velocity of the current being very sensibly diminished within a curved envelope extending forward from the face of the pier and within which a sort of water cushion is formed. Masses of ice are frequently given a rotating movement and possibly strike a less damaging blow, or are frequently carried entirely clear of the structure.

The deposition of concrete *in situ* in paper bags, as described by the author of the paper, is certainly an improvement upon deposition simply from a "skip" and deposition in bags made from a material which is not immediately destroyed.

It would be interesting if Dr. Murphy would state whether he has had opportunity of examining, after any lapse of time, the concrete deposited in the construction of any of the works described, or has been able to judge whether chemical action of sea-water has taken, or is likely to take, place.

The design of the pivot piers at Lockport and at Bear River suggests the question, "has the water free access to the voids within the structure during tidal fluctuations? If not, is there any danger of forced percolation, and consequent chemical action upon the concrete?"

Doctor Murphy has had long and varied experience in the use of Portland cement concrete. It would be interesting if he would express his views as to what are satisfactory tests of a cement suitable for use in such works as are described, in the proportions specified for rubble and for fine concrete.

(1) As to chemical composition; (2) specific gravity; (3) fineness; (4) behavior under the testing machine. Also, his views as to

the right proportions of water to be used in mixing for deposition under such conditions, and any information as to what are safe and what are unsafe atmospheric temperatures for carrying on concrete work.

On some of these points there seems to be diversity of opinion; ignorance of, or inattention to, some of them not infrequently leads in all probability to the making of a very poor concrete from very good materials.

Dr. E. GILPIN.*—As Dr. Murphy has observed, there are few countries more trying to masonry than Nova Scotia. The constant alternations from thawing to freezing during the winter, often taking place twice during the 24 hours, are very destructive to all structures, especially when they are at all porous. The experience of 80 years has shown that no variety of "sandstone" met in Nova Scotia can be relied upon for permanent structure, and the ravages of time are often serious within a period of 30 years. Two methods of attack characterize the disappointments met in brick and stone structures, the disintegration of the mortar as well as of the stone. The only stones that appear indestructible with us are granite and syenite, and the more highly metamorphosed of the slates of the gold-measure rocks. The latter, locally known as "ironstone," have, in some cases, shown not the slightest weathering for about one hundred years. Limestone has been used to a limited extent. Some very old buildings have stood well; other structures have not yet served their apprenticeship to time, and in the case of limestone each quarry must make its own record.

The concrete age which is beginning in Nova Scotia bids fair to displace stone in nearly every respect where utility is more consulted than appearance. The first application of it in Nova Scotia for colliery purposes was for the foundation of a large Cornish pump. This was not satisfactory, owing to want of knowledge on the part of the builders. Later, concrete has been extensively used for engine foundations, in some cases increased strength being gained by imbedding old wire ropes, etc. As a material for dams it is excellent under a slight head of water. As ordinarily built it is too porous for heads exceeding 100 ft. I have observed, however, that if the material be evenly and firmly rammed, so as to leave the minimum of pore space, its resistance to the

* Inspector of H. M. Mines.

passage of water is greatly increased. Under such circumstances the stone should be small and thoroughly worked in.

As a puddling around shafts above the rock head, it is superior to clay, as it is not worn away by the action of any running water. There are other colliery uses to which it is applicable, but I will not here refer to them, as it is sufficient to say that in Nova Scotia it has earned its footing, and that Dr. Murphy has received much commendation for the ready and adroit use he has made of it to extend the funds available for our bridges. This is of no small importance, our rivers being numerous and necessarily bridged near the outlet, as the settlements are principally along the shore.

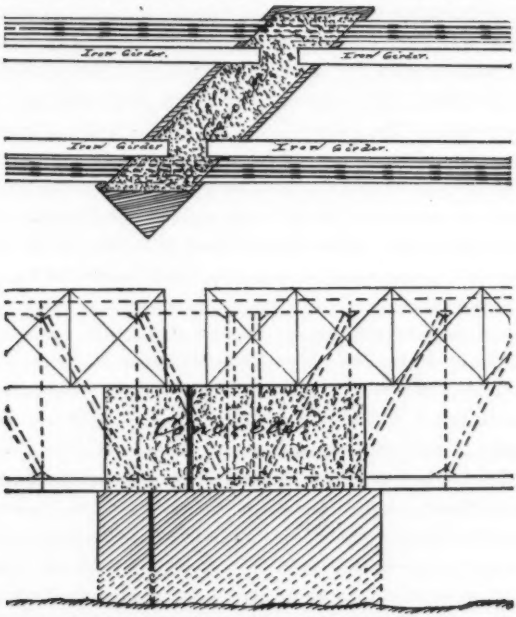
Mr. P. S. Archibald.—The writer is familiar with the various structures described in the author's paper, and can bear testimony to their efficiency and durability. He acknowledges that he had serious misgivings as to the advisability of using concrete for substructures in a climate with such a wide range of temperature as that of Nova Scotia, when the author began some of the works above described. He has, however, had his doubts removed, and for the past five years has been using concrete freely for miscellaneous works in connection with the maintenance of the substructures of the Intercolonial Railway.

In renewing bridges, where it has been found necessary to carry up the height of the piers and abutments, it has been used to great advantage as regards saving of time in the execution of the work, and at about one-half the cost as compared with ashlar masonry.

As an illustration, the writer will briefly describe the renewal of the Rivière-du-Loup Bridge. The old bridge consisted of three wooden spans of 100 ft. each, built on stone piers in a very rapid stream. The trusses were of the "Howe" pattern (deck) and 20 ft. in height. It was decided to replace these with steel spans of the Warren type, 10 ft. deep. This necessitated the building up of the piers and abutments 11 ft. It was the intention at first to build up with solid masonry. The old structure was unusually wide, the piers and abutments extended a very little distance outside of the trusses. The stream was very full, and it was only possible to reach the piers and abutments by lowering the stone with a derrick from the top of the bridge. The traffic over the bridge was very considerable, and it was not practicable to have a derrick set up any length of time on its top. So, under these circumstances, it was decided to try concrete. The old trusses were spread

out a few inches, sufficient to permit of the new spans being erected between them. This brought the old trusses nearly to the outer ends of the abutments and piers.

The chords of the old trusses were 30 ins. wide and took up a large share of the piers and abutments, and in building up the concrete the temporary framework was made large enough to cover nearly the whole surface of the piers and abutments, including the space occupied by the old wooden trusses. These latter were therefore encased in concrete,



as shown on sketch herewith. When the whole was completed and sufficiently hardened, and the new spans erected in place, the old wooden chords and posts were sawn off close up to the face of the concrete, and allowed to fall into the stream below. The old timbers when encased in the concrete were sound. They were chiseled off about ½ in. deep from the face of the concrete, and a coat of cement applied. This concrete has been in use three years and shows no signs of deterioration to date. The cost of it was about $8 per cubic yard. The writer is satisfied that solid masonry would have cost nearly, if not

quite, double that amount. The circumstances, however, were very favorable for the use of concrete; abundance of good clean sand and gravel was to be had near by, while no suitable stone could be got nearer than 200 miles without opening a quarry especially for this purpose. The cement used was the best Portland, and cost, delivered, $2 50 per barrel.

In the past five years the writer has used concrete quite largely in the foundations of turn-tables and miscellaneous machinery, also in bridge substructures and culverts, and in not a single instance has he had a case of failure; even for the foundation of track scales he has found it expedient to use it in preference to masonry. It requires little skilled labor, and no expensive hoisting plant such as is necessary for masonry. The price of good Portland cement is now about $2.10 per barrel, delivered at St. John or Halifax, and when the other ingredients are to be had at reasonable prices, near the site of the work, concrete can be built for less than $5 per cubic yard.

Three years ago the writer had the piers of the Shubenacadie River Bridge treated to a coating of concrete within a timber framework, and has had no trouble with them since. Previous to that, they had been a source of annoyance and expense for 20 years. The masonry here was affected by the flow of the tides, as was that of the Avon Bridge, described in the paper.

Mr. H. S. Poole.—I have knowledge of some of the bridges to which Dr. Murphy refers, and can endorse what he says of the apparent success of concrete foundations, even when made by workmen without special experience. A casual examination readily shows imperfections in the mixing and ramming of the material used and yet no indications are seen of injury from frost, although the climate of Nova Scotia is a trying one, alternations of temperature being numerous, rapid and severe during the winter. I have known a drop of 40° in 12 hours, following a rain storm which left all open structures soaked with water.

Martin Murphy, M. Can. Soc. C. E.—The author attributes the successful employment of Portland cement concrete in the erection of the substructure of the bridges in Nova Scotia largely to the means adapted to carry the work into effect. At first or early stages of progress, the work to be executed was of such a comparatively limited and local character as to be within his own personal control, and was ac-

cordingly let by contract. Later on, however, as the value of concrete became better known and gave a greater degree of confidence, it assumed larger proportions and became more diffused or extended in its application as the bridges under construction became more remote. Hence it was considered that more accurate supervision and more desirable results could be obtained by performing the erection by "day's labor" under the more direct control of the engineer and such assistance as he could procure.

The daily increasing knowledge which regulates the practice of Portland cement, its admixture with the aggregates to form a reliable concrete mass and its final deposition can, in the opinion of the author, for obvious reasons, be better effected by "day's work" or men employed by the day than it can be by contract. Unlike masonry, we have to deal with a material every fragment of which has to be compounded by the union or mixture of elements, on the combination and coherence of which will depend its value and efficiency. The materials have to be selected and their treatment watched with a much greater degree of care than that required for masonry supervision, and this can be better performed by trained hands in the employment of the engineer. The author believes that the failure of Portland cement concrete is more frequently caused by the defective manipulation of the ingredients than by inferior cement. In his experience he has, however, invariably made use of the cement manufactured by White Brothers, of London, England, and its behavior under varying conditions of employment has so far warranted the further continuance of its adoption, and although the other ingredients have not always been as clean, sharp and promising as he could wish to form a reliable concrete, still the structures spread over the Province of Nova Scotia are remarkably free from deterioration or fracture. One thing he is quite certain of, *i. e.*, that, wherever an abrasion or slight flaw shows itself, it is due to careless workmanship and not to the quality of the cement. However, not to be invidious, he should state that he has observed some other brands of Portland cement employed within the Province and equally exposed to tidal fluctuations and to the climatic changes of temperature, already noted, behaving equally well.

The discussion calls for no extended remarks. The gentlemen who have favored us with their views speak from personal observation and from a knowledge of such work gained by experience. In response to

Professor Butler's interrogation, the author has had opportunity, after lapse of time, to examine the concrete deposited under sea water and found no deleterious effects—nothing remarkable, no expansion, disruption or evidence of blowing could be observed. With regard to the voids in the circular piers, the tides rise and fall during ebb and flow, within the same as without. Provision is made against the danger suggested by placing air holes in the top covering, to allow the air forced by the rising of the water to escape.

The properties of a good reliable cement are: It should be finely ground. It should have a specific gravity of not less than 3 at the end of four weeks. It should give the usual tensile strengths with briquettes at 7, 14 and 28 days made with neat cement, and also with briquettes made of 2 or 3 parts of fine quartz and sand and 1 of cement. It should be mixed with a sufficient quantity of water, about 4 galls. to 1 cu. ft. of cement. When too much water is used in the intermixture, a white creamy-looking substance rises to the top of the concrete layer, when tamped. This thin film of free lime more or less divides the mass, separating the continuity of bonds and stratifying the whole, thus destroying its monolithic character. This too frequently occurs by reason of dousing the ingredients with too much water, to save labor in mixing. The author does not believe in excessive tests, more especially tensile tests. A poor cement with an excess of lime may give the best tensile test at seven days, but the induration will not continue steadily onwards with such a cement. One can with some experience determine an excess of lime by the pat test. It is difficult to test cement properly, and a novice cannot possibly do it. The most reliable course to follow is to purchase from the most reliable manufacturers. Extremes of temperature, hot or cold, should be avoided. In summer time with 80° Fahr. and upwards, the concrete should be covered from exposure to the sun and kept sprinkled for six or seven days with a fine sprinkler. In the fall or winter season concrete work should be discontinued in a climate like that of Nova Scotia. where there is risk of freezing. In every case where concrete was placed in piers during frosty weather, when the temperature of the atmosphere was 10 or 15° below the freezing point, the following summer thin scales of concrete would peel off from the exposed surface.

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671.

(Vol. XXX.—December, 1893.)

SUBAQUEOUS FOUNDATIONS.—DISCUSSION ON PAPER No. 626.*

By C. O. GLEIM and F. NEUKIRCH.

A MEMBER.—Has this process been tried, and if so, where?

C. O. GLEIM, Cor. M. Am. Soc. C. E.—The gentleman has suggested just the same thing that I would have suggested, that the author be asked for details of the cases in which he has applied his process. The paper mentions two cases, the one a sewer that had given trouble, being in quicksand, the quicksand being drawn through the masonry and causing a settlement of the surrounding mass; in this case, he says, they have applied the process to the sewer with good success. In the other case he does not give much detail in this respect, and I would like to have the author given an opportunity to add some information on this head.

Mr. F. NEUKIRCH.—In compliance with the desire expressed I beg to give the following details about the practical cases of the execution of foundations according to the method described in my paper.

* "Improved Method of Constructing Foundations under Water by Forcing Cement into Loose Sand or Gravel by Means of Air Pressure." By Fr. Neukirch, C. E., of Bremen, Germany. *Transactions*, Vol. XXIX, page 639.

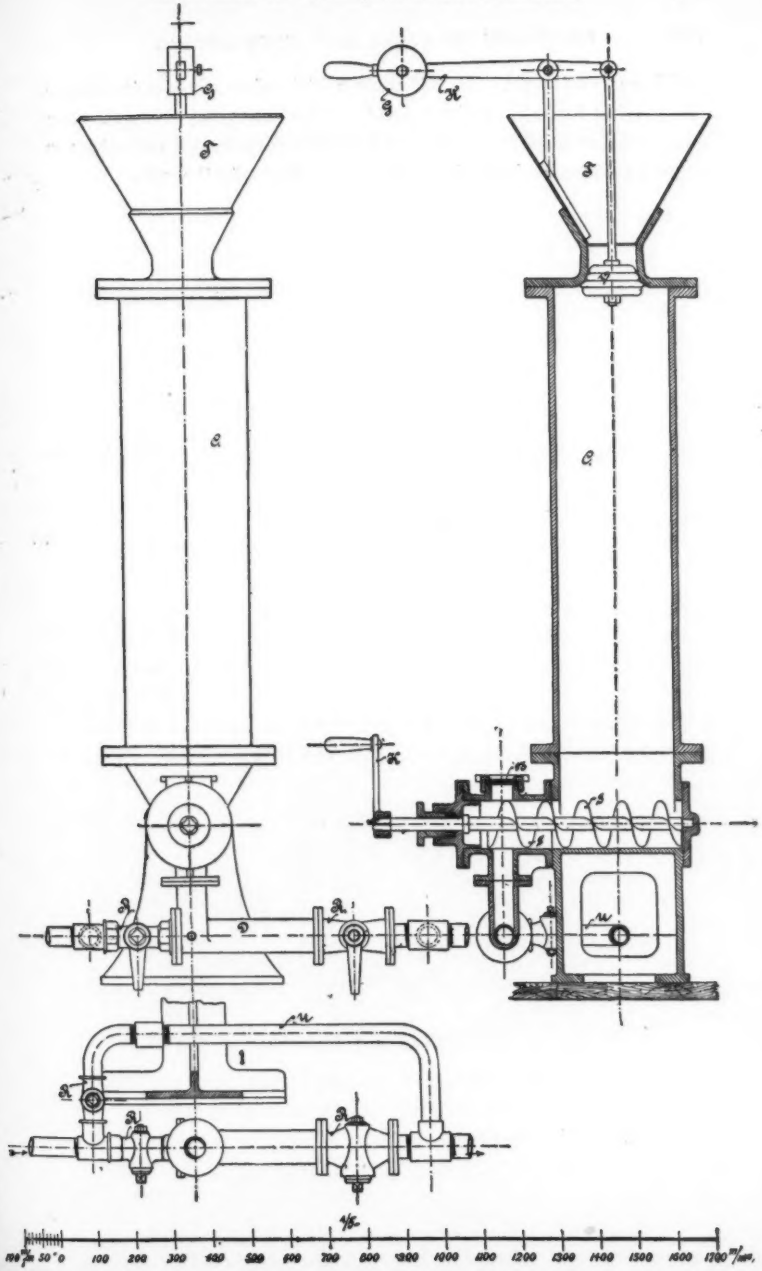
For the work described in Figs. 1 and 2 (Plate I, Vol. XXIX, page 642), a double-acting compressor with direct steam action and increased effect through pressure-compensating slider, patent Burckhardt & Weiss, was employed.

The air cylinder was 270 mm. ($10\frac{5}{8}$ ins.) in diameter.
The steam cylinder " 320 " ($12\frac{5}{8}$ ") " "
The stroke of both, " 305 " (12 ") " "

The compressor forwarded 4 cu. m. (140 cu. ft.) of air per minute, working with 125 revolutions. The maximum air pressure was 6 atmospheres. The air cylinder had a water-jacket, and the compressor was provided with a small pump for the cooling water. The air vessel was 1 m. in diameter, 2 m. long, and was provided with a manhole, a safety valve and a pressure gauge. For producing the steam, the boiler of a portable steam engine that happened to be at hand was used. The compressed air was conveyed to the place of operation through wrought-iron pipes of an internal diameter of 50 mm. (2 ins.). The system of pipes was lengthened or shortened, according to the situation of the place of operation, and was connected by rubber tubing with the traveling stage. In the process shown in Fig. 1, there were 46 580 kg. (102 690 lbs.) of cement injected, and in that shown in Fig. 2, 47 200 kg. (104 000 lbs.).

The apparatus used for supplying the cement is shown on page 581.

The cement is filled in through the funnel *T*, passes the valve *V* and falls into the cylindrical chamber *C*. The valve *V* can be opened by the workman who fills up the cement by means of the lever *H;* it closes spontaneously by the weight *G*. Below the chamber *C* there is a conveying screw *S*, which can be moved by the crank *K*, and serves to convey the cement to the injection device *D*, in which the cement is carried away by the current of compressed air and conveyed to the lance pipe. The pipe *U* serves to convey compressed air direct to the lance pipe without conducting it through the injecting device containing the cement. For this purpose the three cocks *R* are provided. The receiving chamber *C*, which can be shut up by the valve *V*, is required because the holes in the nozzle of the lance pipe might possibly become clogged, and in this case the compressed air would enter through the openings of the injecting device into the chamber containing the cement, which, if the chamber were not closed by the valve *V*, would


1/8
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 m/m.

be blown into the air. At *N* there is a little glass window, to observe the moving forward of the cement by the conveying screw *S*. The chamber *C* is filled every time with such a quantity of cement as is required for each introduction of the lance pipe into the soil.

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672.

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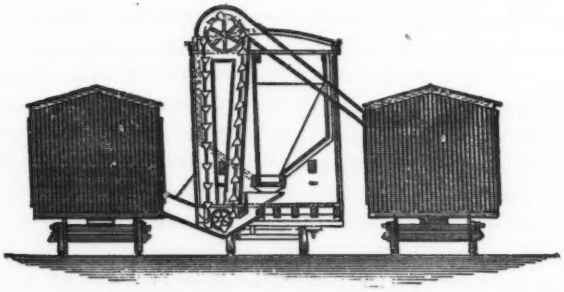
AMERICAN GRAIN ELEVATORS.—DISCUSSION ON PAPER No. 627.*

By EDWARD B. TAYLOR and E. LEE HEIDENREICH.

EDWARD B. TAYLOR, M. Am. Soc. C. E.—I note that Mr. Heidenreich has made no mention of the "Jumbo" grain weighing and transfer car which has been used at Chicago on several of the roads for the past eight years with very good results.

The first car was used on the Pan Handle tracks at Chicago in the summer of 1883, and consisted of a car 35 ft. in length and 15 ft. high



above top of rail. Inside the car, at one end, there was an upright 10-H. P. engine, boiler, and the necessary machinery for a running line of elevator buckets and shovel attachments, the balance of the space in

* "American Grain Elevators." By E. Lee Heidenreich, M. Scandinavian Eng. Soc., of Chicago. *Transactions*, Vol. XXIX, page 644.

the car being occupied by a bin or hopper, of a car-load capacity, resting on a standard scale. In transferring from car to car three tracks are used, as shown in the cut, the transfer car occupying the center track. Steam shovels are used to shovel the grain into an elevator boot at one side and bottom of transfer car, from which it is elevated and dumped into the bin or hopper, then weighed, after which a slide in the bottom of the hopper is opened, and the grain runs a second time to the elevator boot, and is elevated to a spout, by which it is discharged to the car in readiness to receive it. To operate one of these cars requires the services of an engineer and four laborers.

The first elevator built had only a capacity of about 40 000 lbs., but the elevators now have a capacity of 1 800 bushels and a scale capacity of 80 000 lbs. with a 15-H. P. engine, and from 35 to 40 cars of grain can be transferred in 10 hours. The machine has been found to be very useful and economical and well adapted to localities where the business does not warrant the construction of an elevator building.

Mr. E. Lee Heidenreich.—Referring to Mr. Taylor's remarks on my paper on "American Grain Elevators," I will say that in addition to the grain weighing and transfer car which he mentions, and which I often have seen, I also omitted to mention the transportable corn shelling and transfer car which is used to take care of corn from a string of corn cribs along the railroad line. From foreign correspondence I have been reminded of the fact that automatic weighing machinery is largely in use in foreign elevators, and that in an elevator in Fiume, Croatia, electricity is used in transmitting power to different elevator legs, but without any material success. Automatic scales have been used in this country, but have not been brought to a satisfactory degree of perfection, as a possibility always remained for clogging up the inlet or discharge opening of the receptacle by sticks or similar objects which would interfere with the proper workings of the scale. The introduction of a stiff hair brush at the inlet opening seemed to have obviated this trouble in the modern foreign automatic scales. Foreigners claim to have solved the fire-proof bin construction problem by a compound construction in concrete and steel, claiming that the concrete does not cause the condensation of moisture in the same degree as iron or steel; in fact, does not dampen the grain at all, but, in view of actual experiments in this country with cemented brick walls, we cannot consider the problem solved in a manner satisfactory to our grain merchants who are subject to the very strict rules prevailing for the weighing of grain.

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673.

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PAVING BRICK.—DISCUSSION ON PAPER No. 628.*

By DANIEL W. MEAD, WILLARD BEAHAN, F. A. CALKINS and ALBERT SMITH.

A MEMBER.—I would like to ask Mr. Mead if all paving brick are vitrified.

D. W. MEAD, Assoc. M. Am. Soc. C. E.—I believe that many good paving brick that are in use in the United States can hardly be classed as vitrified brick. Among the first paving brick which were used in this country that I have seen are those at Bloomington, Ill., which were made in 1872. These were made from the drift clay, and in the same way that the ordinary building brick are made at that place, that is, in "clamp" or up-draft kilns. They are, however, the "arch brick," and I think that from 30 to 40% of the brick nearest to the fire arches are used at that place for paving purposes. These are hardly to be classed in the ordinary acceptance of the term as vitrified brick. Yet they have been in use 20 or 21 years at Bloomington, and are still in fairly good shape, although some have lost an inch or more in the original height of the brick.

On the Ohio River, in many places, they are using an unvitrified

* "The Manufacture and Use of Paving Brick." By Daniel W. Mead, Assoc. M. Am. Soc. C. E. *Transactions*, Vol. XXIX, page 653.

brick. They are made from a clay which is a poor grade fire clay, and the brick resemble largely in color a fire brick, though in texture they are somewhat finer grained and less porous. These brick are ordinarily classified as a vitrified fire brick, which is, however, an erroneous classification, as a fire brick certainly cannot vitrify and still be classed as a fire brick. These are used quite extensively in paving through Pennsylvania, Ohio and Indiana.

WILLARD BEAHAN, M. Am. Soc. C. E.—Is vitrification necessary, or can a good paving brick be made without vitrification?

Mr. MEAD.—We are not sure that brick must be vitrified in order to make the best pavement, but it must be a first-class hard-burned paving brick if we expect to use it successfully. There is considerable doubt in my mind whether this idea of using none but vitrified brick is a safe one. If we vitrify brick it is not so susceptible to the action of frost, but we are apt to make a brittle brick which will deteriorate in a few years. In regard to vitrification, I would say I do not regard vitrification essential to all paving brick, at least in a great many classes of pavements that receive the lighter traffic. In the heavier traffic, however, and in the higher grade paving brick, it is still an open question as to what the best qualifications for such a brick are.

F. A. CALKINS, M. Am. Soc. C. E.—The tables contained in this paper comprised in Nos. 2–4 and 8, are of value as reference for analysis, method of manufacture and details of laying pavements. The suggested outline for specifications will tend to increase the efficiency of the limited specifications now in general use.

The principal evidence now required for brick pavements are practical tests for endurance under heavy traffic, which time only can supply. To that end the following description of a brick pavement is contributed. This pavement, although young in years, is old in experience, when compared with ordinary brick pavements, is located in Chicago, on South Canal Street, near Harrison, in the freight yard of the Chicago, Burlington and Quincy Railroad Company, and was laid in June, 1890.

This yard is in the form of a parallelogram, 570 ft. in length and 40 ft. in width, with the longest side parallel with the street. The freight house is 555 ft. long, provided with 17 doors for reception and delivery of freight, with a space of about 31 ft. between each. The entrance to this yard is on one side, and not at the end, and is about

400 ft. long, or 155 ft. less than the length of the freight house. It is important that the position of the yard relative to the street be noted, to understand the effect of traffic.

The foundation for this pavement has been a cumulative one, composed of broken stone which has been added to for many years, as the settlement under traffic required; and at time of laying the brick, it had a depth varying from 18 to 24 ins. Upon this foundation a cushion layer of sand was spread from 4 to 6 ins. in depth, upon which one course of brick was laid on edge, at right angles with both the street and freight house. This position of the courses turns a large portion of the traffic parallel with, instead of at right angles to, the paving blocks.

As a team is in position at each door nearly all the time, the space to turn is limited, compelling the driver to turn short and back the wagon for delivery of loads at the end and not from the side, which produces a twisting motion to rear wheels causing them to slide and not roll on the pavement. As this rolling motion is mainly parallel with courses, it tends to increase the destructive action to a greater extent than a uniform rolling load would be at right angles. The traffic on this pavement during the past three years has been heavy.

Men were stationed to count the teams entering and departing from the yard in one day. The tonnage of freight was given by the company, but the weight of teams, wagons and drivers was estimated. The total amounted to 11 157 tons, or 279 tons per square foot of surface. This computation conforms with Captain F. V. Greene's tables.

A recent inspection of this pavement shows that it is in good condition, presenting a fair surface for a pavement under such a heavy traffic, yet there are defects which a careful inspection shows were caused by poor material. All of the bricks are chipped on the upper surface, leaving a smooth surface from 1 to 2 ins. in width. The vertical chipping was from $\frac{1}{8}$ to $\frac{1}{4}$ in. on sound brick, and on some soft brick, 2 ins., yet this chipping does not prevail to such an extent as to impair the usefulness of the pavement. I noticed a few depressions which are produced by soft bricks. There are five depressions about 1 ft. in diameter which were from 1 to $1\frac{1}{2}$ ins. below surface, and one 6 ft. long and 1 ft. wide, 1 in. below the general surface. The bricks at each point could be cut easily with a knife. The adjacent bricks presented a uniform surface.

The forces causing destruction to this pavement appear to be due more to percussion than compression. The greatest amount of chipping occurred at a point where the heaviest traffic passed, at entrance, which would be longitudinal with layers. The next in importance was noticed at points where the horses turned in backing, which coincided nearly with position when at rest during loading.

If the soft bricks were replaced with sound ones, this pavement will endure present traffic many years longer.

The bricks composing this pavement were made in Galesburg, Ill., but are generally inferior in quality to the paving bricks I have examined from that locality.

ALBERT SMITH, Assoc. M. Am. Soc. C. E.—Mr. Mead's paper will be welcomed by municipal engineers as a valuable addition to the literature of an important subject. No doubt many will differ with him in the opinion that "brick will eventually outrival granite under the heaviest traffic," or at least render the Scotch verdict, "Not proven"; but its value where the traffic is moderate, as in small towns and cities and the residence sections of large cities, has already been demonstrated. I would not be understood as advising its indiscriminate use in all such places.

It is at all times the duty of the engineer to secure the best results for the least money, and while in some places the price of good paving brick is such as to make this the natural material, there are other places where one may well question the wisdom of its use, the added freight from many hundred miles of railroad haul increasing the cost above that of other equally good material which can perhaps be found near at hand.

The qualities which go to make a good brick pavement are essentially the same as for a good pavement of any other material. The brick form the surfacing material and must resist the abrasive action of the wheel and the horseshoe, and the disintegrating action of water and frost. The comparative ability of different brick to resist such abrasion is fairly shown by the rattler or tumbler test. Although a rattler can be found at any foundry, it is difficult to find two of the same size or run at the same speed; therefore, make a comparative test with some well-known brick or paving stone. You will certainly do well if you can attain the standard of quality set by F. A. Calkins, M. Am. Soc. C. E. (*Transactions* Am. Soc. C. E., Vol. XXVI, page 391),

viz., first quality, abrasion equal to granite; second quality, abrasion twice that of granite.

Brick should be tough enough to stand dumping from wagons; if they do not stand this they will fare badly under the chipping action of a horse's shoe. Brick must also be able to resist the action of frost, their ability to do so varying in a general way with their porosity; but being also a function of their elasticity or toughness, it seems probable that an amount of expansion from frost which would result in the disintegration of one brick might not produce strains beyond the elastic limit in another brick composed of different material. My experience has been that a maximum limit of 4% absorption in fire clay brick and 2% in mixed clay or shale brick, can be met by the manufacturer, and that within such limits little trouble is to be apprehended on that score. A prime requisite is uniformity in mixing, molding, and burning. All clays must be thoroughly rolled or ground, and should be molded so as to be as free as possible from lamination. Great care is necessary in the burning. If the brick are raised to too high a heat before the "water smoke" is driven off, various defects arise. First, cracked or "checked" brick; second, "scalded" brick, showing a discolored core, generally blue; third, "bloaters," or swelled brick. The next stage is the burning proper, and must be continued long enough to burn the brick clear through. A failure to do this will leave an unburned central core differing in shade, but not in color, from the outside surface. A brick with a core, either from scalding or under burning, is necessarily an imperfect brick. Not only is there a failure to develop the full strength of the material, but the lack of uniformity necessarily induces strains within the brick itself, thereby tending towards its own destruction.

The third stage is the annealing or slow cooling. If this is properly done, the brick, although vitrified or glassy in structure, will have a proper degree of toughness. If cooled too quickly, they will be brittle, a great many will be damaged in handling, and they will be liable to chip up under the action of the horse-shoe.

I see no advantage in round-cornered brick, nor is the repressed paver, as ordinarily put on the market, superior to the ordinary paver in aught but shape. The pressure given is only enough to true up the brick, but not to compact it to any appreciable extent. They stand handling somewhat better and lay closer together in the street, but, so

far as I have tested them, are not quite as strong as the unpressed brick made by the same manufacturers. Apparently the superficial layer affected by repressing defeats the very object aimed at, *i. e.*, uniformity of structure. These remarks would not apply if the pressure were greater. The immense pressures put upon electric light carbons, emery wheels, corundum wheels, etc., certainly have a good effect. These pressures run up as high as 2 tons per square inch, and thus assure a uniformly dense material.

Austin T. Byrne in his excellent book on highway construction (page 152) says: "The foundation should in all cases be formed of cement concrete," and some others hold the same opinion. One might as well say that all railroads should be double tracked and laid with 90-lb. rails. There is no doubting the fact that a good concrete foundation will make a better street than any fragmentary construction, but there are many places where the traffic can be sustained on a much cheaper base (as witness Table No. 8, given by Mr. Mead).

In this list nine towns and cities are reported as using concrete wholly; four use it to some extent, while thirty use fragmentary materials according to their local availability. Personally I have known very good results, both from gravel and broken stone foundations; but have had no experience with a sand foundation, either in connection with tarred boards or an additional course of brick laid flatwise.

A question frequently asked is, "On how steep a grade can brick pavement be used with safety?" The steepest instance within my personal knowledge is that of Main Street, Washington, Penn., where a maximum of 11% is reached and no trouble experienced.

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PRINCIPLES FOR THE LAYING OUT OF CITIES. DISCUSSION ON PAPER No. 632.*

By JAMES OWEN.

JAMES OWEN, M. Am. Soc. C. E.—There are two points about Mr. Stübben's paper which are very forcible and striking: 1st, that the theoretic principles enunciated therein are so in accord with the ideal practices aimed at, but perhaps not adopted, in this country; and, 2d, that the writer, with the surroundings of European practices, where haphazard extension from an accidental nucleus is so much in vogue, should have been enabled to divest himself of the influence of environment and so enunciate the doctrines that he has.

In a new country, such as this is, the possibilities of ideal mural development are infinite and unfortunately seldom realized; in Europe such development is in spite of tradition and the habits and ideas of centuries.

There are, however, principles enunciated by Mr. Stübben in his paper that, with the present ideas of city transit and with its possible future development, seem open to criticism, and I wish to call particu-

* "Practical and Æsthetic Principles for the Laying Out of Cities." By J. Stübben, Baurath and Asst. Burgomaster at Cologne, Germany. *Transactions*, Vol. XXIX, page 718.

lar attention to the matter, as, with the experience in large cities for the last few years for the proper service of vehicular and traction travel, a partial abandonment of old ideas seems necessary.

In the laying out of any city two main factors enter into consideration —suitable location for dwellings and buildings, and ease of access from and to these buildings for the general population. It therefore follows that, considering only the dwellings themselves, a rectilinear system is all that is required, making all blocks square, and, of necessity, all buildings the same. As against this is the desire of the traveling public to get to its destination in the most direct line, and the rectilinear system does not, on the average, allow this. As a relief to the necessity of traveling two sides of a triangle, radiating streets are introduced, and, in many of the cities of this country, are in use, and in a few cases, like the city of Washington, a series of intersecting radial avenues from different nuclei were constructed. This, while thoroughly accommodating the traveling public, sacrifices the land for building purposes, leaving many goring lots and impairing their value.

With the growth of rapid transit and the cheapness of fares the necessity for radial avenues decreases in a marked degree, in consequence of the ability of more people to ride than previously; and so, only such radiating streets as are necessary for the rapid transit should be constructed, and, by that, more of the rectilinear system preserved. In laying and constructing such main arteries, new ideas will have to be in vogue to properly subserve a general interest. As it is now, we have the riding, driving and walking public to consider. All have their rights, and all should be considered. So far the walking public has been unmolested. The driving public now, with cable and trolley roads, is driven out of the main avenues of travel, and the riding public is supreme.

An inspection of the condition of the streets of Chicago at the present time will illustrate the force of the statement; trains of cable cars careening through the main streets of the city, ruthlessly forcing aside all other travel on it, do not constitute a condition that may be considered ideal. Take the city of Boston, in its present congested condition near the Common, and vehicular travel is almost out of the question.

It may be urged that such a condition is tentative, and that a proper solution of the rapid transit problem in all such cities will

remove the congestion. In answer to this, the reply is that, so far, human invention has not been able to keep up with demands of locomotion in cities, and, as long as their population keeps increasing, will probably not do so.

The ideal street in the future must therefore consider all requirements—so much for foot travel, so much for vehicles standing, and so much for vehicles moving, and so much for cars that are propelled. To accommodate all, more room than has as yet been considered requisite must be allowed. The extension of Beacon Street, Boston, into Brookline is an instance of about what is necessary. It is 150 ft. wide, and about fills present requirements, and in any new city development a width of main arterial street less than 150 ft. should not be considered.

There are many other points in Mr. Stübben's paper worthy of allusion, but I merely wish to call particular attention to what I consider a vital point.

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MANUFACTURE AND TESTING OF PORTLAND CEMENT.—DISCUSSION ON PAPERS NOS. 633* AND 634.†

By D. J. WHITTEMORE, R. W. LESLEY, WILLIAM MURRAY BLACK, Sir BENJAMIN BAKER, WALTER ROBERT KINIPPLE, JOHN PURSER GRIFFITH and HENRY FAIJA.

D. J. WHITTEMORE, Past President Am. Soc. C. E.—While not prepared to discuss the able papers under consideration, I wish to call your attention to the elaborate paper written by Captain Maclay and read before the Society at a recent meeting, advocating certain severe tests not generally advised either in England or Germany. My own opinion is, that the boiling is of little or no value in determining the ultimate quality. The effect of immersion in warm water is to increase activity of induration; but when immersion takes place in boiling water, the steam generated in uncombined water in the immersed specimen may, and probably does, produce a disruptive effect upon the best cements. American engineers wish to secure a uniform cement, and one that is finely ground. It is, I think, a question whether we should test ce-

* "The Testing of Portland Cement and the Development of the Cement Industry in Germany." By Max Gary, C. E., Berlin, Germany. *Transactions*, Vol. XXX, page 1.

† "On the Manufacture and Testing of Portland Cement." By Henry Faija, M. Inst. C. E. *Transactions*, Vol. XXX, page 43.

ments by compression, and not rely entirely upon tensile tests. If we wished to ascertain what a man could sustain on his shoulders, we would not attempt to ascertain the tensile strength of his neck. Cements are generally used in compression, and more tests of that nature should be had. While the ratio between the tensile and compressive strength of Portland cement appears to be practically constant, this is not the case with many of our natural cements of America.

In conclusion, I wish to say, that it is my belief that the quality of Portland cement has not materially changed or been improved since the close of the investigations of the late John Grant, M. I. C. E., were published. As I now remember it, he established that the cement he used in the metropolitan works of London should withstand a tensile strain of 250 lbs. per square inch at the age of seven days, the last six being in water, while it is a common practice in this country to exact a tensile strength of 375 lbs. per square inch. In explanation of this apparent difference in the demands, with, as I believe, no great difference in quality, I wish to say that Grant's tests were made on specimens having a breaking area of $1\frac{1}{2} \times 1\frac{1}{2}$ ins., or an area of $2\frac{1}{4}$ sq. ins.; while tests, both in England and America, are now made on briquettes having an area of 1 sq. in. Perhaps it will be borne in mind by some of our members that in a paper read before this Society by myself some years ago, it was shown that briquettes of the same cement, having breaking sections varying from $2\frac{1}{4}$ to $\frac{1}{4}$ sq. ins., the unit of measure of strength was not the area, but the periphery, of the breaking section, that is to say, that the total strength of briquettes of different sizes, but of the same cement, when divided by the length of the circumscribing line of the breaking section, gave approximately the same resulting quotient. This being the case, then Grant's requirement of 250 lbs. per square inch for $2\frac{1}{4}$-in. area of breaking section would be as severe as a demand of 375 lbs. for a section of 1 in. square. This being the case, is of itself a strong argument for the establishment of a universal standard briquette.

To some considerable extent the same rule holds good in the tests of stone, brick, glass, and other substances of a brittle nature, when tested in short lengths.

R. W. Lesley, Assoc. Am. Soc. C. E.—In discussing the two papers which have just been read, and the comments that have been made upon them by Mr. Whittemore, there seems to me to be quite a number of

matters that are of considerable interest, and I should like to call attention to several of them.

In the first place, upon the question of hot tests, I would say, commenting upon what has just been said by Mr. Whittemore, that he is entirely right in his assertion that the paper of Captain Maclay has set forth a violent test for Portland cement, and one which controverts the practice of the Germans and also the leading authorities in England. This is not only the case so far as concerns the first consideration of the subject by the Society of German Cement Manufacturers, but is also the case as to their later tests. The question has been the subject of their consideration for three years, and in the last Proceedings of that Society, of which Mr. Gary is a member, the Association has just resolved, after further investigation, to adhere to its regular cold water test and to dispense with any boiling test. These results have been arrived at after a series of tests covering a period of nearly five years, and are the final conclusion of the leading society of this character in the world.

In connection with this German society, which in some of the papers upon the boiling test has been stated to be governed in its adoption of tests by the "financial interest," as though it were an association of manufacturers only, it may be stated, and its proceedings show, that at all the meetings the German government is represented by its Director of Testing Department for Building Materials, as well as by representatives from public works, post office and other departments of the German government, and that furthermore the standard tests adopted by that society are recognized by the Minister of Public Works in Germany as the official test in that country.

The opinion of Mr. Faija, who is one of the leading authorities in England upon this subject, also practically sustains the same view. His test is a very simple one so far as any heat is concerned, and it suggests that the pats of cement, when made, shall be put upon a little shelf in a closed tin vessel, where moisture is arising from water kept at a temperature of about 116° Fahr., and that, after a few hours of this exposure, these pats shall be placed in water at about 116° Fahr., and shall, after 12 to 15 hours of this treatment, be examined for checking. The effect of this test is almost the same as covering briquettes with a damp cloth in sunlight, and is certainly a test that is efficacious so far as determining the quality of cement is concerned, while on the other

hand it is not destructive, as are the accelerated tests in the various papers read on this subject by Captain Maclay and other cement chemists, as distinguished from engineers. In order to determine the effect of the test described by Mr. Faija, and of the method described by Mr. Maclay, I took a well-prepared Portland cement clinker, grinding it to a fineness to pass 90% on a 10 000-mesh sieve, made the material into pats, and put the pats through both modes—those of Faija and those described by Captain Maclay. The tests show, as I have always claimed, that there is a time in the chemical setting of cement, when, if there is any extraneous influence brought to bear upon the cement at the particular moment mentioned, the setting is retarded, sometimes entirely prevented, and sometimes driven into violent action.

In the test described by Captain Maclay, four pats are made which are put into the water at various periods. One of these pats is placed in a steam bath, temperature 195 to 200° Fahr., as soon as it is made. The second pat is placed in the steam bath as soon as it is set hard and can bear the 1-lb. wire. The third pat is placed in the steam bath after double the interval has elapsed that it took the pats to set hard, counting from the time of gauging. The fourth pat is placed in the steam bath at the end of 24 hours. The four pats are each kept in the steam bath three hours, then immersed in water of a temperature of about 200° Fahr. for 24 hours each, when they are taken out and examined. Out of these pats which were exposed to tests under this method, none showed any disintegration except the third pat, which had been left in air two hours and then in water; whereas, the pats made with the same cement, tested under Mr. Faija's method and subjected to the slow moist heat, then to water at 116° Fahr, showed no disintegration whatever. From these facts I am of opinion that the accelerated test above mentioned certainly is not as fair to the cement as the test suggested by Mr. Faija. In other words, as we all know, if there is one thing that no man can give an opinion on, it is the exact moment when the cement sets—one can say it can be told by the needle; this needle can be pressed upon the pat within ten minutes after set, or within an hour after setting. Another will say that the set can be told by tapping the cement with the nail—this nail may be long or it may be short, and there is an equal uncertainty about the moment of setting. The whole action of setting is a chemical one, and there is a moment in the chemical setting of cement, as the experiments above referred

to show, when, if the cement is disturbed, it will not give the result; and for this reason, it seems to me that boiling pats at high temperatures will never give absolutely correct results and this test should certainly not be adopted from the authorities so far before us.

As against this, the German report follows out a series of experiments made by the Society, and gives results of these experiments and the effect which followed the boiling test, the record of the cements which had stood all the requirements in water, air and in the work, and yet which had failed to stand the accelerated test. It follows out these results carried out at three years, and also the result of other cements, which had failed to stand the boiling test, carried out to a longer period.

The same matter of accelerated tests has been up before the French Society of Engineers of the Ponts et Chaussées, in France, where it was sought to introduce such a test as one of the elements of the standard specifications for work in that country, and, at a late meeting, the French authorities reported against an adoption of such test, so that upon the broad principle of the adoption of accelerated tests in this country, we are left with the fact that the consensus of opinion of the German government, the French government, and the leading cement authorities in England, together with the suggested specifications of the American Society of Civil Engineers in our country, is all against the adoption of any such test.

It is a very gratifying thing to find that Mr. Gary, Mr. Faija and Mr. Whittemore all agree in their views as to the use of this boiling test, and, as engineers, sustain the views of engineers upon this subject, as against the experimental laboratory tests that have been suggested.

Referring briefly to some of the points in Mr. Faija's paper, his specification seems to be a very fair one, inasmuch as it requires a cement of moderate tensile strength at seven days. This would enable the manufacturer to make fine ground cement, which in the neat tests will not test as high as the coarser ground cement made with the same clinker, but will test high in sand mortar. In the matter of grinding, the American manufacturers are following the Germans rather than the English, and the bulk of American Portland cement will pass 90 to 95% on a 10 000-mesh sieve; results of this cement would show on a 1-in. section about 300 to 350 lbs. at seven days neat, and from 200 to 300 lbs. at seven days in 2 to 1 sand mortar; the sand mortar showing the

sand carrying effect of the fine grinding, while the low figures in the neat test are due to the same cause, which usually retards the neat test.

Mr. Faija's paper gives a very interesting description of the various kinds of machinery in use in England, and, in connection with this matter of fine grinding, he makes some comparisons between stone mills and iron mills. In this country we have solved the problem of grinding cement by the use of iron mills, which certainly grind a larger quantity and give more satisfaction in the manufactured product than stone mills do. We have also overcome the objection to mill stones suggested by Mr. Faija, viz., that of having one stone always up being dressed, because in the cement mills in this country all the mill-stones are made interchangeable, and, by having one extra pair of stones, all the mills may be run and still a pair of stones be dressing, the loss of time being only the moment of taking one pair of stones out and putting in the other.

In our practice here, we have also overcome the difficulty of making the brick too dense for burning, which Mr. Faija states is the difficulty that arises in making brick in brick machines. By our practice we find it is better to take the raw material, and, after pugging, to spread it on floors and then cut it by hand. This makes more porous brick than those made by machine, and, at the same time, makes brick in the best possible shape for burning.

One of the most interesting things in connection with sand tests of cement, and one which possibly few engineers have thought of, is that the effect of the sand test is not only to get the result of a cement, but also to get the result of the sand actually used or to be used in the work; that is to say, while a series of tests of a number of cements with the standard sand of the American Society will give the varying elements of the several cements used, so a series of tests with different sands made with a single established brand of cement will give the comparative results of the various sands proposed to be used. Interesting experiments of this character were made with certain red sand used in the brickwork of the Niagara Tunnel, and tested on a comparative basis with the standard sand of the American Society. Similar tests of the same character have been made on the New York Aqueduct, the majority of briquettes especially referred to in paper on the Sodom Dam, read by Mr. W. McCulloh, being made with sand actually used in the

work, and many others being taken and made direct from the mortar in the mortar-boxes. At one of the Scranton dams, near the city of Scranton, Penn., there was a great deal of trouble about the sand, and work was suspended at one time while the matter was being investigated. The sand at that time was being brought from some distance to the work, and a suggestion was made to test the sand found in a hill near by. As a result of the experiment, all the sand being tested with the same cement, and a similar set of tests being made with the standard sand of the American Society, in which the same cement was used—results were arrived at that showed that the sand near the work was very much better than the sand that was being brought from a distance, and by comparison between it and the sand of the American Society there was very little difference. In this way a large amount of money was saved the contractors in their work.

Some remarks have been made in Mr. Gary's paper in the matter of abrasive tests of cement, and machinery for the purpose of making these tests has been fully described by him. In this country, the question of abrasive tests for cement came up in connection with the Niagara Tunnel, where a large body of water was to be dropped at a certain point in the tunnel, and the best proportioned mortar was desired for use in that connection. Dr. Coleman Sellers took the matter in hand and made a number of experiments, to arrive at the best results in this direction. The method used by him, and which he will no doubt describe in proper time, was by means of a sand blast, and the results of his experiments were very much in the same lines as those shown by Mr. Gary.

Another thing which may be of interest is the difference in the several machines for testing tensile strain. The German machine and the Fairbanks machine are very much alike, being automatic and having shot running into a bucket at a uniform rate of speed, the breaking of the briquette causing the bucket to drop and thus cut off the supply of shot. The bucket is then weighed, and the strain is registered on the scale. The other machines largely in use in this country are the Riehle and Olsen machines. These machines consist of a long beam, at one end of which is the briquette, and at the other end of which is a fixed weight. On the beam on which the pounds are registered is a movable weight. In manipulating the machine, the operator uses one hand to turn the screw below the briquette so as to

tighten it up and with the other pulls the weight along the beam, keeping his eye on the needle so that the strain may be kept even throughout. These machines on long-time briquettes, give better and more uniform results than the shot machines, but on short-time briquettes, owing to the personal equation of the operator, very frequently give incorrect figures. In the testing laboratory of Booth, Garrett & Blair, in the city of Philadelphia, a very interesting improvement has been made to one of these beam machines, in order to make the work of the machine more uniform. In this device a grooved wheel has been substituted for the hand wheel, by which the operator applies tension to the briquettes; a cord runs in the groove and from it around a pulley on another shaft suitably placed. Motion is given to this shaft by means of of a disc sliding on a feather on the shaft. The disc's rim bears on the face of another disc at right angles. The shaft which carries this second disc runs steadily by power, but, by shifting the rim of the first disc across the face of the second, the speed of the pulley-shaft can be changed at pleasure, from fast to slow, or to the dead center. The weight can thus be applied to the wheel at the rate of 400 lbs. per minute, and the operator simply has to turn the small wheel that draws the weight along the scale beam. Briquettes broken on the machine thus operated show a breaking almost uniformly at the central section, and show average results considerably better than on the same machine operated entirely by hand.

William Murray Black, M. Am. Soc. C. E.—I desire to invite the attention of the Society to the necessity for tests for the relative value of different brands of cement for sea work. I was in charge of some work in St. Augustine, Fla. There, you may know, the sea water is very salt and the heat of summer very intense. In 1886 we had to do some work with Portland cement concrete in air and in water. The cement that we had was an English Portland, and stood all the usual tests. The sand that we used was very fine, but a sand that afterwards gave very good results indeed. It was almost entirely silica. The only coarse material that we had there was shell. In that vicinity there are large banks of broken shell, called coquina gravel, and that material was used because stone could not be obtained without too great expense. The proportions used were 1 of cement, 2 of sand, and 4 of shell. The concrete was used in three places; first, in an

arch in air; second, at the foot of a sea-wall, which was exposed at low water; and third, in some blocks which were made for tests, made in air and left to dry in air for a week, and afterwards placed in sea water. The arch in air rapidly became very hard. After two years I was obliged to drill a hole through it, and it was as good concrete as any one could desire. At the same time it became necessary to excavate at the foot of the sea-wall. We found the concrete there very soft. I then took up the test blocks that had been lying near by in the sea and examined them. The concrete of the test blocks and of the sea-wall had become very soft, looked like scoria in texture and the color had changed. I had the matter investigated as well as I could, but could not determine the cause for the change, and could not find any test that would enable me to guard against future deterioration in similar work. The only thing I found it possible to do to guard against such deterioration was to call for and use some brand of cement which had stood successfully under similar conditions for five years. I doubt not that a large amount of concrete of the foundations of sea-walls is practically worthless. As concrete in foundations is subjected to compression strains, and as the strength is generally well within the factor of safety, this may not be discovered. I found that engineers whom I interrogated on this subject generally could not tell me anything about the later state of the concrete they had used under such conditions.

Another instance of concrete softening might well be noted. The concrete foundations of Forts Taylor and Jefferson were laid about 1856. This concrete was made with Rosendale cement, calcareous sand and shell. About 1876 a portion of the sea-wall at Key West was repaired with concrete of the same materials. Portions of this concrete are covered at high water; when the water falls, small puddles are left at any places where it will lodge, and is acted upon by a very hot sun. Along the top of the wall where these puddles are found, you can take a penknife and sink it in the concrete to the length of the blade; along the side of the wall where the water does not stand, the skin is left on, and the concrete is hard. We had another experience when in Florida which shows the strength of concrete necessary to resist abrasion by wave action, in putting in some concrete just at a point where it would be exposed to surf at every high tide. It was placed at low water. The concrete was made in blocks and protected by

strong boxing. About a day and a half after we got the blocks in we found that a portion of the boxing had been torn off during a heavy gale. We had made quite a number of test pieces of the same concrete at the same time, and these were kept under conditions quite similar to those to which the walls would be exposed. We removed the remaining boxing from the block of concrete after a week and found that the surf had cut in in some portions and that other portions of the block were perfectly solid. In testing the concrete test blocks, we found that wherever the concrete had not attained a tensile strength of 30 lbs. per square inch before exposure to the waves, it was abraded; where it had attained to 30 lbs. per square inch before exposure, it was intact.

Sir BENJAMIN BAKER, Vice-President M. I. C. E.—Mr. President, I think that although the literature on this matter would fill this room, still engineers are not in accord upon the subject. The Manchester Ship Canal and the Liverpool Water Works are instances; the specifications require the tensile strength to be at least 80% higher in the one case than in the other. I know both works, and on the ship canal there are some hundreds of thousands of tons of cement. I paid a visit of inspection just before I came over and carefully examined all the great works of the docks and sluices, retaining walls, inverts and locks, and I failed to find cracks, except in some places where they would generally be found, namely, at the outside angles of walls returned at right angles. In the case of the canal works, the cement was of low tensile strength, about 300 lbs. per square inch. On the other hand, in the instance of the great masonry dam of the Liverpool Water Works, one of the largest in the world, the cement was specified to be about 80% higher than on the ship canal. The engineer was entirely satisfied, as there had been no cracks whatever. Both engineers, indeed, were perfectly satisfied with the results. These engineers were familiar with all the literature on the subject, and with the views of English and of foreign engineers, and yet we have that great divergency in practice. Others say we never had any trouble with cement 30 or 40 years ago, when the matter was left to the experience of the manufacturer, and engineers did not insist upon tests.

Of course, in masonry structures the direct tensile stresses are small, but shearing stresses are a very important question, and in many respects you will see that failure by crushing is really a failure by

shearing. In all the many experiments which I have made with concrete blocks and concrete columns, some of them 2 ft. square and 12 ft. long, I found the strength directly proportional to the quantity and tensile strength of the cement, and that the failure generally occurred by a longitudinal split down the column.

There is one point in Mr. Gary's paper which I really rose to speak to. He says, with regard to the setting of cement, "it is best to employ Vicat's regulation needle," which may have been true a few months ago, but is not true now, because an autographic machine is used now, of a simple character, which any instrument maker could make. That is, instead of a needle, a small wheel is used, loaded with a few pounds weight and traversed by clockwork. A pen attached to a lever traces a curve of sufficiently large scale to constitute a permanent autographic record of the rate of setting of the cement from minute to minute.

WALTER ROBERT KINIPPLE, M. Inst. C. E.—Mr. Faija's paper deals with the manufacture and testing of Portland cement, but engineers, as a body, are more concerned with the cement after it has been manufactured, and it is important that simple, reliable, and, as far as possible, expeditious methods of ascertaining whether cement be sound and fit for use, should be well known.

Mr. Faija has set forth very clearly the usual tests, but there is one addition which I have found to be useful, and have adopted in a number of the works which I have carried out. That test is to form a thin plate of Portland cement 12 ins. square by $\frac{1}{4}$ in. in thickness on the surface of a piece of plate glass, surrounded by a metal border, or framing, standing up $\frac{1}{8}$ in. above the surface of the glass. Through the cement plate, near to one corner, after it has slightly set, a hole is pierced for the purpose of hanging it up by a piece of wire or string.

When the plate has firmly set, it is hung up in the testing-room, and carefully observed, from time to time, to see whether any cracking of its surfaces or edges takes place, or any tendency to twist, and I have always found with good cement which has been duly cooled, that the testing plates keep their form, and no signs of cracking ever appeared; and, further, that the plate, when hung up by a wire or string, gave a clear, musical sound, which I found to be that of E flat, in almost all cases. With cement which was inclined to blow, the plate did not maintain its form, nor did it give forth the musical sound referred to.

I have in my possession some plates which have remained true planes since first formed, while there are others which have gone to pieces or become twisted, to a considerable extent.

By forming such large, thin plates better results are obtained than by the usual round plates of a few inches in diameter, by about ½ in. to 1 in. thick in the center, which I have frequently found do not show defects until a very long period after the plates were made. I have some in my offices at present, which are only now falling to pieces after having been made some eighteen months.

The grinding of cement is most important, and for the application of it, in the form of thick paste or grout of neat cement, for the purpose of cementing together stone or shingle or large blocks under water in the construction of monolithic or submarine work, fine grinding is highly important. To this system of submarine monolithic work I have devoted 35 years' attention, and have carried out many undertakings based thereon. My experience with cement for this purpose shows that it should be very finely ground, and that the ordinary sieve of 2 500 meshes per square inch is not sufficiently fine.

My specification for cement for this class of work is that it should pass through a sieve of 6 400 meshes to 1 sq. in., and for the St. Helier Harbor Works, Jersey, where many thousands of tons of cement were used, this was the specified firmness, and excellent results were obtained therefrom. With cement passing through a 2 500-mesh sieve, some of which was tried, decidedly inferior work was obtained.

A small parcel of cement ground to pass through a sieve of 10 000 meshes to the square inch, was likewise used on these works and gave the greatest satisfaction, and had it not been for the extra price per ton which the makers required for cement of this fineness, I should have had only this fine floury cement used on the work.

Mr. JOHN PURSER GRIFFITH.*—Mr. President, I sincerely trust that this paper of Mr. Faija will be fully discussed. The subject is of world-wide importance to our profession, and I believe that this is the first opportunity which we have had of hearing the views of engineers of all nationalities. For almost a quarter of a century I have been engaged in harbor work, and it has been my privilege to be associated with one of our most distinguished British engineers, Dr. Bindon B. Stoney, in the improvement and maintenance of the harbor of Dublin.

* Of Dublin, Ireland.

We have used Portland cement largely and with great success, and it will readily be understood with what interest and anxiety we have heard of some of the recent failures which have occurred in marine works constructed with Portland cement. I have endeavored to investigate the causes of these failures, and I am glad to be able to say that in the majority of cases they have been due to the manipulation of the cement, and not to any fault in the cement itself.

We have had in England a magnesia scare, as it was alleged that the presence of magnesia in the cement was the cause of many failures, and it has been proposed to limit the proportion of magnesia present in Portland cement to a very small percentage. It is now generally admitted that the presence of large quantities of magnesia in the concrete where these failures occurred was due to the percolation of sea water, which had decomposed the cement, and that the remedy, or rather the preventive, for such a state of affairs is to make the concrete impermeable.

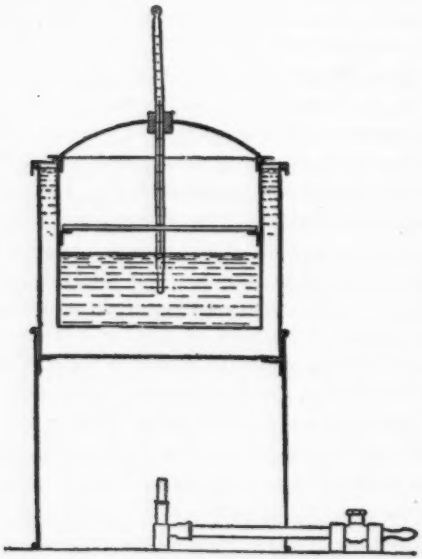
Germany has adopted standard tests for cement with very great advantage, both to consumers and manufacturers. I believe that Germany owes much of its success in the manufacture of Portland cement to these tests, and I am indebted to my friend, Mr. C. O. Gleim, of Hamburg, for much information on this point. In England, unfortunately, we have no standard tests, and the result is that engineers there have to be more continually on their guard against dangerous cement. That such dangerous cements are to be met with in our markets, I have had ample proof. One instance in particular comes to my mind. It is the case of a cargo which passed the specified tests for tensile strength and fineness satisfactorily, and yet after a time showed signs of disintegration, which led to its rejection for use on our works. On examination by an expert cement manufacturer, the materials of which it was composed proved to be correctly proportioned, and subsequent experience has satisfied me that its defect was due to being lightly burned, and not finely ground. Coarse particles in a cement of this kind hydrate more slowly than the finer particles, and this is followed by expansion and disintegration of neat cement briquettes. If this cement had been ground to a uniform degree of fineness, I have little doubt that it would have proved a thoroughly safe cement. German Portland cement is, as a rule, much more finely ground than English cements, and this is due to the adoption of the mortar test for testing the tensile strength

of cements. The rule adopted there of testing the strength of a mixture of cement and sand, instead of cement alone, has compelled the cement makers to grind their cement very fine. Beyond proving the value of fine grinding, I see no advantages in the sand test over the neat cement; but I do see disadvantages, namely, that it introduces a a second element of uncertainty into our tests. It is all very well to say that we should use a standard sand, but it has been proved, over and over again, that sand obtained even from the same district and of the same grade of fineness will give very variable results. These are some of the reasons why the sand test has not gained ground in England. At the same time, I must freely admit that those who have used the sand test have got the best ground cement. I should much like to hear this point discussed here, for I think now that it is so generally admitted that the finer a cement is ground the better; it is quite possible to get all we require by testing for fineness with very fine sieves, and for strength with neat cement, and thus avoid the secondary issues raised by the introduction of sand into our tests.

HENRY FALIA, M. Inst. C. E.—I am extremely pleased to find that Mr. Kinipple recognizes the importance of a test that definitely determines whether or no a cement is sound, as it corroborates a theory which I have for many years propounded, viz., that, given a cement which proves itself to be sound and free from either expansion or contraction, it is, in 99 cases out of 100, strong enough for all constructive purposes, and the support of an engineer of Mr. Kinipple's eminence, and who has used more cement than most people, is most gratifying. The test, however, which he proposes is, I think, a little cumbrous and occupies some little time, certainly, except in the case of abnormally bad cements, a few weeks, and I fail therefore to see that it supersedes my own test for the same purpose, which is fully described in the paper. It has now been in very general use for more than 10 years, and enables a perfectly reliable determination being arrived at within 24 hours. A sketch of the apparatus used in this test is given in a paper which I had the honor of communicating to the American Society of Civil Engineers in 1886; but perhaps, in order to bring the matter more forcibly before the notice of cement users, the following sketch (see page 608) will render the description given in the paper more complete.

With respect to the fineness of grinding to which Mr. Kinipple and

Mr. Griffith both refer, I think there are now no two opinions on the matter, as it has been most conclusively proved and established that the finer a cement is ground, the better work it will produce; this result is due to the cement being in greater subdivision and thereby enabled more perfectly to surround each of the pieces of aggregate with which it is mixed, thus giving greater strength or allowing of less cement being used. Such being the case, it is a matter for the manufacturer to say to what degree of fineness he can grind the cement without extra or exorbitant expense, and the economy of fine grinding is therefore defined by the balance between the cost of grinding and the use of more cement; but I would again refer to that portion of my paper in which I pointed out that fineness of grinding, unless the powder is in the form of flour, is very delusive.



It is hardly necessary to refer to Mr. Griffith's remarks about the magnesia scare which obtained here some few years back. I went into the matter very carefully at the time, both theoretically, chemically and practically, and the results of my experiments were com-

municated in two papers to the Society of Engineers in England, and as they brought forth no tangible refutation from those who started the magnesia scare, it may fairly be assumed that my experiments were taken as conclusive, and that the deduction I arrived at, viz., that a good and properly used Portland cement is not detrimentally affected by sea water, is correct.

The absence of a standard specification in this country, which Mr. Griffith laments, has, I think, rather conduced to the production of a better cement than had we been governed by a specification drawn up 15, 10, or even 5 years ago. Had such a specification been in existence there is no doubt that the manufacture in this country would have been to a certain extent limited to compliance with that specification, and would therefore not have improved in the manner which it has. I am quite willing to admit that many of the specifications submitted to manufacturers, and with which they are requested to comply, are often worse than stupid, and, although the manufacturer may be quite unable to comply with them, still they have forced him to do something out of the ordinary, which in the end has resulted in an improved manufacture. While therefore deprecating many of the clauses which are inserted in cement specifications, and while I would myself never condemn a cement because it does not absolutely comply with those terms, I would on no account prevent the layman from writing such specifications as he thinks fit.

Mr. Griffith's remarks about the sand test are quite in accord with my own views, as it is well known that I have from the very commencement fought against the introduction of an extraneous and unknown material into a cement test. Through the universal introduction of the sand test in Germany, the production of cement in that country has resulted in what I should call an adulterated cement, and this is to a certain extent acknowledged by the Germans themselves, as in their own directions to manufacturers it is specially stipulated that no cement shall contain more than a certain percentage of adulterating material. The particular adulterant which is used is sulphate of lime, which not only renders the cement slower setting, but adds somewhat to its adhesive powers. At the same time if this adulterant much exceeds 3 or 4%, it renders the cement an absolutely dangerous one to use, and it seems to me that it is wiser to be satisfied with a good honest Portland cement that perhaps develops a little less tensile strength when

gauged with sand, than one which gives the maximum in this test, but which, by a very slight error in manufacture, may result in the destruction of the whole of the work in which it is used.

I have only to tender my thanks to the Congress for the kind manner in which my paper was received.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

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676.

(Vol. XXX.—December, 1893.)

TOPOGRAPHIC SURVEYS.—DISCUSSION ON PAPER No. 635.*

By CHARLES B. BRUSH, KENNETH ALLEN, HENRY GANNETT, MARCUS BAKER and HERBERT G. OGDEN.

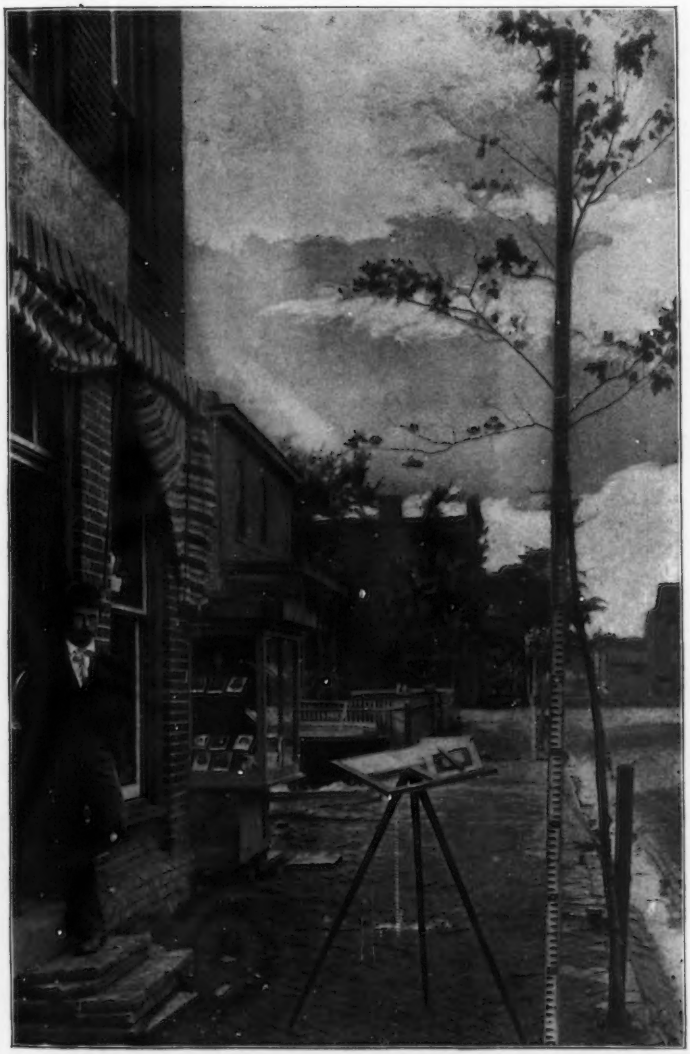
CHARLES B. BRUSH, M. Am. Soc. C. E.—Some of the most interesting exhibits to be seen at this wonderful Exposition at Chicago are the numerous relief maps. I do not know of anything which has interested me more than the relief map of the New York State Canals and of the Nicaragua Canal. They are advanced types of this class of work.

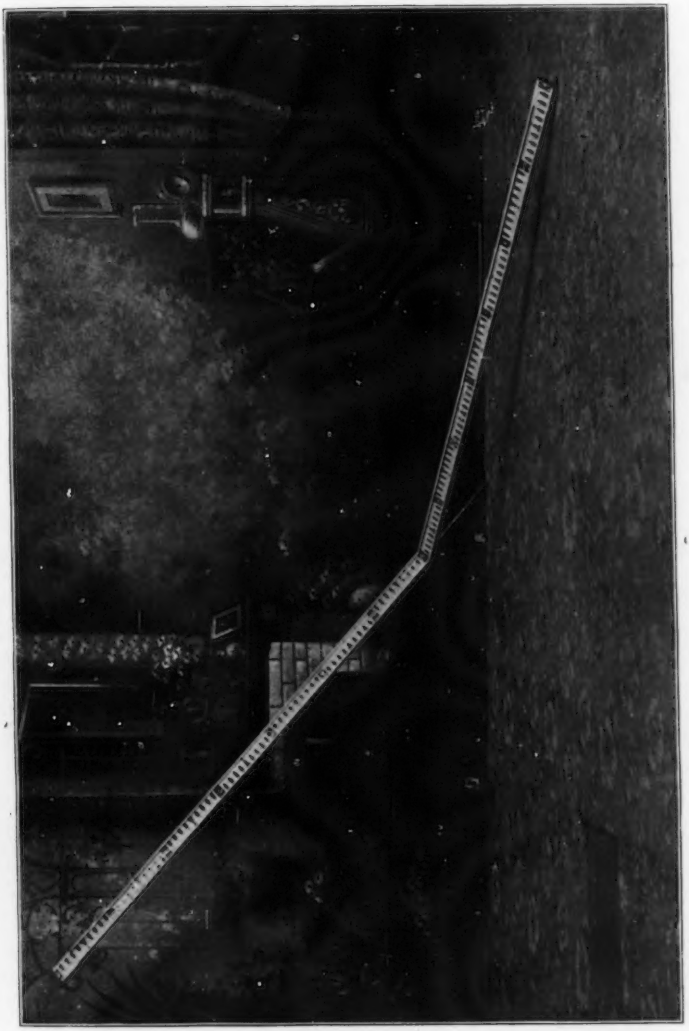
In relation to the topographical maps of the United States, I do not know of any as complete as those of the State of New Jersey. This, I believe, is the only one of our States that has a complete topographical map of its whole area. In New Jersey, these maps have been found to be of great value and are extensively used. Separate sheets of different parts of the State can be purchased to any extent for 25 cents each. These maps were prepared under the direction of Professor Cook, State Geologist.

* "Topographic Surveys." By Herbert G. Ogden, Assistant U. S. Coast and Geodetic Survey. *Transactions*, Vol. XXX, page 62.

KENNETH ALLEN, M. Am. Soc. C. E.—Mr. Ogden's paper is one of great interest in showing the development of topographical surveying in this country. This development has been both in the increased extent of the work done, in field methods and in mapping; and in each of these particulars it has been marked. The surveys of 40 and 50 years ago, valuable as they were at the time, were scarcely more than a compilation of more or less faithful sketches as regarded the actual relief, this being indicated generally by the use of hachures with the occasional elevation of summits and thalwegs. To-day, by the aid of the stadia and vertical arc, the modern range finder, the aneroid and the camera, we are enabled to conduct our topographical surveys with ease and expedition, and hence with economy; and by the introduction of contours of known elevation supplemented only by the occasional use of hachures, our maps indicate the hypsometric features with a precision dependent only on that of the field work and on the scale of the map.

The degree of precision is so dependent on the field methods employed, however, that these, if not indicated in some way on the completed map, should at least be known by those who make use of it. Where such a diversity of methods exists as is quite proper, considering the great difference in topography in various sections of the country and the specific purposes for which surveys are made, it would seem highly desirable that the execution of State surveys should be based upon some such rules or criteria as those formulated by the conference of topographers referred to by Mr. Ogden. For the greater number of surveys where contour intervals of from 5 to 25 ft. are employed, the writer believes, from its use on surveys covering some 600 sq. miles, that there is as yet no more expeditious, economical or flexible method developed than by the employment of the stadia in the ordinary surveyor's transit. It is adapted to every character of country, may be used in parties of from two to six men, depending on the ground and the price of wages, involves but about $10 extra cost in the instrument, and can be used with the ordinary Philadelphia rod, if a special stadia rod is not at hand. In ordinary work in a hilly country, circuits of from 1 to 3 miles in length are run, checking on benches when possible, elevations being determined with the vertical arc. Such circuits, with ordinary care, will check within 1 or 2 ft. in elevation and about 15 ft. in horizontal





distance. With triangulation points not over 3 or 4 miles apart, bench marks established every square mile or so, contours 10 ft. apart and the scale of the map not over $\frac{1}{3000}$, the above error will not be found excessive; while, if greater or less detail and precision are required, the method may to a certain extent be adapted to it with economy.

There are one or two points pertinent to the occasion with regard to instruments. The aneroid is a most useful aid to one who understands its use and its limitations. Many surveying aneroids, as manufactured, carry a vernier on a scale of feet to be read with a glass to single feet. Now, where such accuracy is employed in reading, it is disconcerting to be obliged to make a very appreciable correction for temperature. It would seem more rational to employ the foot scale for very rough work only, and have the vernier on the pressure scale, to be used on more refined work.

The writer has found that with most men, in fair weather and an open country, it is of great advantage to plot the work on a small sketch table mounted on a tripod in the field. On a recent survey of the Connellsville coke region, a number of these were made, having four removable sections over which skeleton sheets containing all known cadastral points were stretched, these four sections being interchangeable in the frame. When the two eastern ones, for instance, were finished, they were shifted to the west side of the table, and fresh sheets were inserted in their places. This avoided folding or overlapping sheets, which had previously been found objectionable. A 14-ft. folding stadia rod was also devised with a graduation which was at once simple, distinct and serviceable. At very long range mirrors inserted at certain points on the rod were easily distinguished, and aided in avoiding mistakes.

In the survey referred to, the area covered was 168 sq. miles, lying in a tract about 44 miles long and in no place over 5 miles wide. For local reasons, traverse circuits were run with steel tape and transit as the base of the survey—in all, 220 miles in length. After plotting on a scale of 600 ft. per inch, the error in a number of these circuits was found to be about 3 in 10 000. The work was done by ordinary chainmen, partly over very hilly ground, and partly along the railroads. Where an error was suspected, the line was re-run.

No angular error in a circuit was allowed to exceed 5′, but

there was obviously no way to control an accumulation of angular error in a tract of this description. Observations for the meridian were taken, however, either on a star or the sun at eight points, averaging about 6 miles apart from one end of the region to the other, and connected with the traverses. The resulting angular errors, after eliminating the effect of divergence of meridians due to the earth's curvature, were in the order of their occurrence as follows: 0′, — 3′.5, + 8′, + 5′, + 14′, — 0′.5, 6′.5, — 6′.5. The average angular error in the 52 separate circuits was 2′.05, the maximum being 5′.

Mr. Ogden's data as to the cost of topographical surveys is valuable to those States that, following the example of New Jersey, Pennsylvania, Massachusetts, Rhode Island, Connecticut and New York. are agitating the question of inaugurating State topographical surveys, The following figures may be of interest in that connection. On surveys occupying 162 days' field work, made in 1884, for the Philadelphia Water Department, with 10-ft. contour intervals and plotting on a scale of 400 ft. per inch, the party consisting of one transitman and one rodman, the average area covered per day taking notes was 0.434 sq. mile, average area covered per day plotting in the field was 0.310 sq. mile.

	City of St. Louis.	Connellsville Coke Region.	Croton Water-Shed.	Surveys, Philadelphia Water Department.	New Jersey, State Geological Survey.	Massachusetts Topographical Survey.	United States Survey, Southern Appalachian Region.
Area, square miles	44	168	400	446	7 514	8 900	14 200
Contour interval	3	10	20	10	10 & 20	20	100
Scale of map	$\frac{1}{2400}$	$\frac{1}{19200}$[a]	$\frac{1}{63360}$[b]	$\frac{1}{19200}$[c]	$\frac{1}{62500}$	$\frac{1}{62500}$	$\frac{1}{125000}$
Total cost per square mile	$732 80	$116 36	$17 50	.....	$9 00	$13 00	$4 00

a — Scale of original map ..... $\frac{1}{7200}$

b — " " ..... $\frac{1}{21120}$

c — " " ..... $\frac{1}{4800}$

On a survey in the Connellsville coke region for the H. C. Frick Coke Company, Mr. J. H. Paddock, Chief Engineer, which was similar in character to the above, but made with greater accuracy and fullness of detail, and plotted on a scale of 600 ft. to 1 in., the cost in salaries

for field work on topography alone was not far from $40 per square mile. The parties consisted of four men, and plotting was generally done in the field. The total cost per square mile includes, besides the total cost of topographical survey proper, the location of coal out-crops, of all farm boundaries, tabulation of coal areas of each piece of property, observations for meridian, latitude and longitude, and the reduction of all previous surveys of the company to the Scottdale meridian The cost of engraving and publication was in addition $5 275.

The increasing demand for State topographical surveys, as well as for those of less extent, indicates a corresponding appreciation of their value in a variety of fields. The meteorologist and the geologist are aided materially by the data thus made available, and with a reliable contour map at hand the preliminary surveys for railways, canals, water supplies, drainage and irrigation schemes, and for sewerage systems, may be partially or totally avoided, saving, in time, much more than the cost of the survey. It remains for the topographer to select from a multitude of methods and instruments, for the conduct of the survey and the projection and reproduction of results, such as are best adapted to the particular character of the territory with which he has to deal—its extent, the ultimate purpose of the survey, and, last but not least, the means at his disposal to accomplish the work.

Mr. Henry Gannett.*—Mr. Ogden's paper summarizes the views of one of the leading officers of the Coast and Geodetic Survey concerning the topographic map of the United States of the future. It states what, in his opinion, or rather, in the opinion of a conference of topographers of the U. S. Coast and Geodetic Survey, should be the scale, the contour interval, the degree of detail, the maximum allowable errors, and the features which this map should represent. His paper is of special interest to me, as I have from the beginning been in practical control of the survey and construction of the map of the country, which the U. S. Geological Survey is making, and I am pleased to see how closely these ideas and my own are in accord.

Thus Mr. Ogden advocates using a scale of 1:30 000, which, where the features are large and bold, may be reduced to 1:40 000. The Geological Survey is using in the northeastern States a scale of 1:45 000; in the Mississippi Valley and on the plains a scale of 1:31 680, and in the Rocky Mountain region, where the features are large and bold 1:63 360.

* Chief Topographer, U. S. Geological Survey.

It is believed that the last of these scales is amply large for the representation of the essential detail in this bold mountain and desert region. It is to be noted that both Mr. Ogden and myself refer here to the scales of the plane-table sheets, not of the maps as published.

Mr. Ogden advises a contour interval of 20 ft. in the level regions of the country, increasing the contour interval where the relief becomes more pronounced. The U. S. Geological Survey uses, as a rule, the 20-ft. interval. In Florida, where the relief is comparatively slight, it uses a 10-ft. interval, and in Southern Louisiana, where the relief is trifling, a 5-ft. interval is employed. In the Rocky Mountain region the interval ranges from 20 or 25 ft. upon the plains and deserts, up to a 100-ft. interval in the high mountains. Mr. Ogden advises mapping the outlines of wooded areas, as being of importance from many points of view. The U. S. Geological Survey maps these outlines of wooded areas, but does not consider it advisable to publish them upon its larger scale maps, inasmuch as the timber outlines are changing rapidly, but it does propose to publish them upon maps on smaller scales. Mr. Ogden's list of the works of man, or culture, which should be represented, comprises little besides objects which may be denominated public culture; that is, objects which are of interest to the community at large rather than to individuals only. The only exception which I note to this statement is that of houses. The Geological Survey early adopted as its policy in this matter the representation of objects of public culture only. Within recent years it has departed from this practice to the extent of adding houses, and with this addition its list of objects of culture represented agrees very closely with that suggested by Mr. Ogden.

As to the limit of error set by Mr. Ogden, it may be asked how the errors of the map are to be determined absolutely, since any work done to test the map is itself liable to error. Thus the stipulation that the height of a hill shall be within 5 ft. of the true height implies a knowledge of the true height of the hill, but how is this to be obtained. It may be suggested that verification of a map can be made by a duplication of the work and a comparison of the results, but this will show, not the errors of the original map, but the discrepancies between the two maps, either of which may be in error.

We can estimate roughly the value of the computed triangulation by the closures of the triangles. We know that graphic triangulation

carried on by the plane table proves itself, since, if sensible errors are introduced, the work falls to pieces. We can detect errors of magnitude in traverses made by the plane table, by their closures upon triangulation points, and we can detect errors in sketching by a comparison of the map with the ground. But since we have nowhere anything absolute to compare with, I do not see how we can measure the amount of errors of location, and say that the position of an object is in error to a greater or a less extent than that admissible, except where the errors are gross.

Now as to cost. The cost of the topographic work of the U. S. Coast and Geodetic Survey at present, including the triangulation upon which it rests, is about $200 per square mile. It is not to be understood that the work in the interior would cost as much, since the scale which Mr. Ogden proposes is much smaller. He estimates its cost at $35 to $45 per square mile, or, say, an average of $40 per square mile. At this rate, the survey of the whole United States, excluding Alaska, would cost $120 000 000. It is not at all probable that the United States would authorize so expensive a piece of work to be undertaken.

On the other hand, the work of the Geological Survey, which is pursued practically upon the plan advocated by Mr. Ogden, has cost for the past three years an average of $5 per square mile, the cost ranging from $3 upon the western plains to $10 in New England and New York. The total cost of the work, one-fifth of the country having been completed already, will not exceed $15 000 000, being but a small fraction of the sum above estimated.

This great difference in cost requires an explanation. A part of it can be very simply accounted for in the difference in policy governing the work of the two organizations. The policy of the U. S. Coast and Geodetic Survey has been throughout to attain the highest possible degree of accuracy. The Geological Survey, on the other hand, aims only at such accuracy as is required for the specific purpose in hand, as the engineer in constructing a bridge apportions the strength of each member to the strain it is to bear.

In pursuance of its policy, the U. S. Coast and Geodetic Survey locates by triangulation and computes the positions of a large number of points, many times the number required for instituting plane table-work. Moreover, it spends time and money in attaining a degree of

accuracy in the location of these points many times greater than is required for the map. The U. S. Geological Survey, on the other hand, locates by triangulation and computes the position of a minimum number of points, three to each plane table sheet, relegating the work of location thereafter to graphic methods with the plane table, which are, of course, much cheaper and of sensible accuracy. Moreover, the location of points in its primary triangulation is only of such accuracy as is required by the scale of the map, since errors which are not sufficiently large to show upon the map are not errors in a map sense. This proportioning of means to ends reduces the cost of the work of the U. S. Geological Survey by nearly one-half, since triangulation, such as is executed by the U. S. Coast and Geodetic Survey, costs, according to their own statement, very nearly as much as the topographic work proper, while the triangulation carried on by the U. S. Geological Survey probably costs not more than one-tenth as much as the topographic work.

But this does not account for the entire difference between the cost of the work of the U. S. Geological Survey and Mr. Ogden's estimate, and I cannot help feeling that his estimate is needlessly high, even for work which may be done by the organization which he represents. The figures given for the U. S. Geological Survey are not estimates. They are the results of experience covering a term of years and hundreds of thousands of square miles, and certainly are entitled to greater credence than any estimates.

There is another item to be considered besides expense in this matter, and that is time. An expenditure of $40 per square mile implies slow progress or a very large annual appropriation. At present the U. S. Geological Survey is spending about $250 000 annually in topographic work, at an average cost of $5 per square mile. Its average annual output is about 50 000 sq. miles. To survey this area at a cost of $40 per square mile would require an annual appropriation of $2 000 000. It is not at all probable that Congress would support it to this extent. The alternative, therefore, is slow progress. Now, if maps are of value to the industries of the country, and we all agree that they are, that value is enhanced by the rapidity of the work. The sooner we have maps, the more use will they be to our industries. Roads, railroads, irrigation works, aqueducts and other improvements are being constructed all the time, and the more of

them which have the benefit of maps, the greater is the utility of those maps. The more rapidly this work can be pushed forward to completion, other things being equal, the more valuable it will be, and, therefore, in considering plans for this work, the item, not only of expense, but of time, should receive due consideration.

Under an annual appropriation of $250 000, the U. S. Geological Survey maps 50 000 sq. miles, and will finish the map of the country, excluding Alaska, in 50 years. This, it would seem, is sufficiently long to wait for it. But under Mr. Ogden's estimate, with the same appropriation, 6 250 sq. miles would be the annual output, and the entire map would be finished in the year 2373, 480 years from the present date.

Mr. MARCUS BAKER.—Some months since I compiled from published sources some memoranda respecting the cost of making topographic surveys and maps. Such data in compact form, it was believed, would be useful for reference. It seems the more important to do this because the question of cost has been to some extent a matter of controversy.

The subject is one of great practical importance, and it seems to me that the statements of cost given by Mr. Ogden may profitably be extended. This opportunity is therefore taken to offer these memoranda for publication as a contribution to, or extension of, that part of Mr. Ogden's interesting and valuable paper relating to the cost of topographic surveys.

FOREIGN SURVEYS.*

India.—It is not easy to get figures showing cost of foreign surveys that are of much value for comparison with similar figures for the United States. Diversity of conditions, of country surveyed, of scales, of purposes for which the maps are made, etc., greatly affect cost.

The country whose conditions appear to be most nearly like our own, and whose experience, therefore, is of most value to us, is India.

In India 10 years' experience in making maps on the 1 in. to 1 mile scale gives a cost of $11 per square mile, and on the 4 ins. to 1 mile scale a cost of $26.50. A similar 15 years' experience in cadastral mapping on the 16 ins. to 1 mile scale gives a cost of $82 per square mile.

* Most of the data for foreign surveys are compiled from Captain George M. Wheeler's Report upon the Third International Geographical Congress and Exhibition at Venice, 1881. 4to, Washington, 1885.

In the Madras presidency 65 935 sq. miles were mapped on scales of 16, 4, 2 and 1 ins. to 1 mile for a total cost of £71 824, or about $5 50 per square mile.

The town and island of Bombay were surveyed between 1865 and 1872 at a cost of £31 306 = $152 000, the area being 22.23 sq. miles, or at an average cost of $6 815 per square mile.

The ratio of scale to cost in the Indian work is estimated by General Walker, chief of the Survey, to be 16 ins. to 1 mile, 7½; 4 ins. to 1 mile, 4; 1 in. to 1 mile, 1; *i. e.*, the 4 ins. to 1 mile map costs four times as much as the 1 in. to 1 mile map. Similarly, the 16 ins. to 1 mile map costs seven and one-half times as much as the 1 in. to 1 mile map.

Austria-Hungary.—Area, 241 550 sq. miles. An entirely new survey of the monarchy was ordered in 1872. Scale adopted, 1 : 75 000; number of sheets required, 720. Original plane table sheets are on a scale of 1 : 25 000. Relief expressed by hachures, contours and figures. No good estimate of the cost of this map is available. Captain George M. Wheeler, in his report upon the Third International Geographical Congress at Venice, from which most of these statements relative to foreign surveys have been taken, says, p. 275: "An estimate was obtained of the cost of obtaining the field notes (1 : 25 000) for the new special map at approximately $400 per square mile."

Baden.—The area of Baden is 5 820 sq. miles, and since 1875 a detailed topographic survey, scale 1 : 25 000, has been in progress. The resulting contour map is to consist of 170 sheets. The cost of the work is stated to be—

For field and office work	$11 90	per square mile.
For engraving and printing....	10 30	" "
Total	$22 20	" "

Bavaria.—The area of Bavaria is 29 280 sq. miles. A cadastral survey (no elevations shown) on a scale of 1 : 5 000, begun in 1808, was finished in 1860. The cost of this survey is estimated at $79 per square mile.

For many years a topographic map has been in progress. The surveys for this consist of a revision of the earlier cadastral map with the addition of elevations and drawing of contours. The amount expended for the work of the Topographic Bureau from the beginning of

its work down to 1885 is estimated at $1 750 000, or at the rate of about $60 per square mile for the whole country.

The current field cost of the altitude determinations, topography and revision, is stated to be from $9 to $13 per square mile.

Belgium.—Area, 11 375 sq. miles. All mapped on a scale of 1 : 20 000, and 1 : 40 000; contour interval, 1 m. Has been undergoing a complete revision. This revision has cost about $23 per square mile. An estimate made a few years since gives $176 as the cost per square mile of the Belgian surveys. The cost of engraving is stated to be about $6 50 per square inch.

France.—The director of the survey states the cost of the surveys of precision by the engineer brigade (scales 1 : 10 000 and 1 : 20 000) to be 100 francs per square kilometer, or about $52 per square mile.

The cost of the survey of Algeria, scale 1 : 50 000, is, for field work, 20 francs per square kilometer, and for engraving, printing, etc., 40 francs per square kilometer, a total cost of about $31 per square mile.

Great Britain.—Area of the United Kingdom, 123 180 sq. miles. Total expenditures for the Ordnance Survey from its creation in the last century down to 1881 was $22 725 000, giving an average expenditure for surveys of $184 per square mile.

The cadastral survey of the United Kingdom, scale of map 1:2 500, began in 1862, and has cost an average of 23d. per acre, equal to $294 per square mile.

Italy.—In 1862 Italy began the preparation of a general topographic map of the entire kingdom on a scale of 1 : 100 000, the map to consist of 277 sheets. The original field maps are on a scale of 1 : 25 000 and 1 : 50 000, with contours 5 and 10 m. apart, respectively. The area of the kingdom is 111 400 sq. miles, and the cost is estimated at from $3 300 000 to $5 000 000, making a cost of from $30 to $45 per square mile.

The director of the survey in 1885 estimates the cost of a single sheet, area 625 sq. miles, of the 1 : 100 000 map at $1 000 for triangulation, and $2 400 for the topography, if done on the 1 : 50 000 scale, but $7 200 if done on the 1 : 25 000 scale, or at a cost of from $5 44 to $13 12 per square mile.

Prussia.—Area, 159 950 square miles. A topographic map is now in progress on a scale of 1 : 100 000. The original sheets are on a scale of 1 : 25 000, with contour intervals of 5 m. (about 16 ft.). The pres-

ent rate of cost for this map is, for triangulation, $22 45; for topography, $28 35, and for drawing, engraving and publishing, $20 10 per square mile, a total cost of about $71 per square mile.

Russia.—Of the topographic work now in progress, and which has been in progress since 1870, the director estimates the cost at 29.5 rubles, or about $22 per square mile.

Cost of Topographic Surveys in the United States.

United States Geological Survey.—The Geological Survey began systematically to make a contour topographic map of the United States in 1882. It adopted three scales, 1 : 250 000, or about 4 miles to 1 in.; 1 : 125 000, or about 2 miles to 1 in., and 1 : 62 500, or about 1 mile to 1 in. The contour interval has varied from 5 to 250 ft. according to scale of map and character of country to be mapped. Early in the history of the work much was done on the smallest scale and little on the largest scale. At present and for a few years past the smallest scale work has been abandoned, and a steadily increasing amount of work has been done on the largest scale.

The total area mapped from the beginning to June 30th, 1893, is 583 922 sq. miles, and the total cost for all expenditures whatsoever necessary to produce the finished manuscript map ready for the engraver is $2 496 776, an average of $4 27 per square mile.

The items of cost include all salaries, instruments, repairs, supplies, superintendence, disbursement for, not only the topography proper, but for all astronomical work, base measurement, triangulation and leveling, etc., which are auxiliary thereto.

The areas mapped on the different scales are approximately as follows:

1 : 62 500	80 000 sq. miles.
1 : 125 000	300 000 "
1 : 250 000	200 000 "
Total	580 000 "

The following table shows the cost by years from the beginning to the end of June, 1893. The first column gives the fiscal year; the second, the total appropriation for the survey; the third, the total appropriation for topography; the fourth, the percentage of the ap-

propriation for topography to the whole appropriation; the fifth, the area mapped, in square miles; and the sixth, the cost per square mile.

UNITED STATES GEOLOGICAL SURVEY.

Cost of Topography.

Fiscal Year, ending June 30th.	Appropriation.	Topography.	Percentage of appropriation.	Area. Square miles.	Cost per square mile.
1883	$256 940	$70 700	27	15 000	$4 71
1884	339 640	88 600	26	45 150	1 96
1885	489 040	160 000	33	57 500	2 78
1886	503 240	184 510	37	81 829	2 25
1887	503 240	204 656	41	55 684	3 67
1888	503 240	202 310	40	52 062	3 88
1889	605 240	278 200	46	64 472	4 32
1890	494 657	336 200	68	67 650	4 99
1891	618 615	361 200	58	65 575	5 51
1892	589 600	266 200	45	53 000	5 02
1893	376 100	249 200	66	26 000	9 58
All	$5 279 552	$2 401 776	45	583 922	
From New Jersey (say)		25 000			
Massachusetts		40 000			
Rhode Island		5 000			
Connecticut		25 000			
		$2 496 776		583 922	$4 27

This average cost is derived from work on three different scales. As the scale affects the cost, the following specific cases—New Jersey, Massachusetts, Rhode Island and Connecticut—of work executed under the direction of the U. S. Geological Survey, and all on the 1 in. to 1 mile scale will afford useful data in determining the cost of that class of work in the thickly settled eastern part of the United States.

New Jersey.—The topographic survey of New Jersey was begun in 1877 and completed in 1887. The total area of the State is 7 894 sq. miles, and the cost of making the contour topographic map designed to be as accurate as the scale of 1 in. to 1 mile will admit of, was $54 744, being at an average cost of $6,93 per square mile.* Of the total cost, about one-half was borne by the State, and the remainder by the Coast and Geodetic Survey and by the U. S. Geological Survey. This cost covers all expenses whatsoever incurred in the production of the manuscript map ready for the engraver. The scale of the drawing was 3 ins. to 1 mile; contour interval, 10 and 20 ft. In his final

* Geological Survey of New Jersey, Annual Report, 1887, page 15.

report, Dr. Cook, State Geologist of New Jersey, estimates that the cost would have been not to exceed $10 per square mile in case the State had been required to execute its own triangulation for the control of the map.

Massachusetts.—The State of Massachusetts was mapped by the U. S. Geological Survey, in co-operation with the State, in the years 1884 to 1888. The resulting map, on a scale of 1 mile to 1 in., and with 20-ft. contours, contained on 53 atlas sheets, cost, for all expenses of every kind and character necessary to the production of the manuscript map ready for the engraver, $107 800. Of this amount, $40 000 was paid by Massachusetts, and the remainder by the U. S. Geological Survey. The average cost of the Massachusetts survey was $12 97 per square mile.

Rhode Island.—The State of Rhode Island was mapped, in the years 1888 and 1889, by the U. S. Geological Survey, in co-operation with the State. The map produced, composed of 15 sheets, similar to those in Massachusetts, cost $9 732 51, one-half of which was paid by Rhode Island and one-half by the U. S. Geological Survey. Taking the area of the State to be 1 085 sq. miles, the average cost was $8 97 per square mile.

Connecticut.—The State of Connecticut was mapped by the U. S. Geological Survey, in conjunction with the State, during the years 1889 and 1890. The total cost of the survey for expenses of every kind and character, such as salaries, traveling expenses, subsistence, pay of men in office engaged in drawing the maps, etc., including everything necessary to the production of the manuscript map ready for the engraver, was $48 999. One-half of this cost was paid by Connecticut and one-half by the U. S. Geological Survey. The area of the State being 5 004 sq. miles, this gives an average cost per square mile of $9 79. This work, done under the direction of the U. S. Geological Survey, yielded a manuscript map of the State composed of 33 atlas sheets, all on a scale of 1 mile to 1 in. and with 20-ft. contour intervals.

Perkiomen Water Basin.—A survey of this basin, for increasing the water supply of the city of Philadelphia, was made by Rudolph Hering, M. Am. Soc. C. E., under direction of Colonel William Ludlow, M. Am. Soc. C. E., and completed in 1885.

The survey comprises an area of 446 sq. miles in Bucks, Montgomery, and Lehigh Counties, Pa. Scale of the map, 400 ft. to 1 in.,

or 1 : 4 800. It has 10-ft. contours and shows all roads, buildings and timber outlines.

I am informed by Mr. Henry Gannett that the cost of this work was stated by Mr. Hering to be $145 per square mile.

Mississippi River Commission.—A topographic map of the banks of the Mississippi River from Cairo to the Gulf of Mexico was completed by the Mississippi River Commission in 1884. The manuscript maps on a scale of 1:10 000 embrace the river and a strip of land on either bank about ½ mile in width. The river was carefully sounded, and the resulting map of the river and its shores represents an area of 1 954 sq. miles of land and water surface, of which the cost was $99 930, or $51 per square mile.*

Lake Survey.—A survey of the northern and northwestern lakes was made between 1841 and 1881, by the Corps of Engineers, U. S. A. The total sum expended on the work was nearly $3 000 000.

The shore line was accurately surveyed and topographic maps made of a strip along the shore about ½ mile wide. This work was based on a careful triangulation, was done on a scale of 1:10 000, and cost for the topography and the triangulation executed for topographic purposes somewhat more than $125 per square mile. The triangulation executed for control of a long and narrow strip of topography is available for a wider strip. If, however, a wide strip is not surveyed, the cost of the area is increased. The cost of $120 per square mile is the amount estimated by General Humphrey and General Comstock as the cost of accurate topography on a scale of 1:10 000, when mapped in considerable bodies. The cost of the topography of the Lake Survey in 1872 and 1873 was $326 per square mile, but this was exceptional, owing to a relatively large amount of triangulation and small amount of topography executed in those years.

Coast Survey.—The Coast Survey created in 1807 did its first surveying in 1817. It was interrupted the following year and resumed in 1832, since which date it has been carried on without interruption. The cost of the topography executed by it has been the subject of controversy, and several estimates have been made. These estimates differ widely. Some of them are here given.

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* Report of the Mississippi River Commission for 1884, being Appendix W W of Report of the Secretary of War. H. of R. Ex. Doc. 1, Part 2, 49th Congress, 1st Session. Vol. 2, Part 4, p. 2574.

Professor Bache, second superintendent of the survey, in 1848 estimated* that the topography proper executed in 1847 had cost $13 76 per square mile; but if the base measures, triangulation, reconnaissances, astronomical and magnetic work be included, then the cost was $27 71 per square mile.

General C. B. Comstock in 1875, from data published in the Coast Survey reports for the five years 1864–68, estimated† that the triangulation had cost $343 per square mile, and the topography $241 per square mile, making a total cost for each square mile of land surface topographically mapped, $584.

This estimate was warmly repudiated by Mr. C. P. Patterson, then superintendent of the Coast Survey, who declared‡ that the most expensive piece of work executed by the Coast Survey for many years was that of Mt. Desert, Me., and that its cost for all expenses whatsoever was $97 per square mile, while other areas had cost only $23, and yet others only $12, per square mile.

Thereupon General Comstock made a new estimate§ of the cost of the topographic work executed by the Coast Survey, from data published by the Coast Survey for the 14 years 1858–72. This new estimate, based on 14 years' experience, gives as the average cost per square mile of the areas within which the topography and triangulation were completed and the map published, as $403. This result is obtained by charging the whole appropriation to three classes of work, viz., triangulation, topography and hydrography, the cost of the three classes being $120 for triangulation, $283 for topography, and $80 for hydrography. The total cost of the topography, including the triangulation by which it is controlled, is therefore on this estimate $403 per square mile.

Captain George M. Wheeler in 1886, made an estimate‖ of the cost of the three great classes of Coast Survey work, viz., triangulation, topography and hydrography, based on its entire experience, from the beginning in 1807 to 1886, and concludes that the 32 000 sq. miles then topographically surveyed had cost $333 per square mile, $25 being chargeable to triangulation, and $308 to topography proper.

* Coast Survey Report, 1848, pp. 3–4.

† Sen. Ex. Doc. 21, 45th Congress, 3d Session, p. 12.

‡ H. of R. Ex. Doc. 29, 45th Congress, 3d Session, p. 2.

§ Sen. Ex. Doc. No. 21, Part 2, 45th Congress, 3d Session, p. 2.

‖ Wheeler (G. M.), Report on Third Geographical Congress at Venice. 4to, Washington, 1885, p. 533 *et seq.*

The Hon. Hilary A. Herbert, after carefully reviewing the foregoing estimates, gives a figure of $250 per square mile* as an estimate not unfair to the Coast Survey.

To this list of estimates I will add one more. And this estimate is designed to get at a fair evaluation of the cost of the topographic work now in progress and such as has been done in the past few years, rather than to get at the cost from the beginning.

The Coast Survey report for 1890, the latest one received, contains a detailed and classified statement of expenditures, and thus affords the data for determining the cost of various classes of work for that year.

From it we have, neglecting odd dollars and cents—

Party expenses, 1889–90	$156 290
Permanent salaries	235 500
All other expenses	116 580
Total expenditures	$508 670†

In this same report the party expenses are classified under thirteen heads, which, arranged in groups, are as follows:

Hydrography	$51 878
Physical hydrography	6 510
Tidal operations	5 111
Coast pilot	4 500
Magnetics	3 900
	$71 899
Topography	$25 032
Triangulation in immediate connection therewith	23 757
	$48 789
Transcontinental geodetic triangulation	$21 032
Triangulation for States	7 175
Precise leveling	3 040
Astronomical work (longitudes)	2 646
Gravity experiments	1 700
	$35 593

* H. of R. Report 2740, 49th Congress, 1st Session, p. 77.

† This figure is from the Digest of Appropriations for 1889–90. The Coast Survey report for 1890 gives as the appropriation $530 458 13; and as the expenditure, $485 992 76, leaving an unexpended balance on hand of $44 465 37. If this balance was turned back into the Treasury, the above sum should be diminished by $22 667; if it was all used, the sum should be increased by $21 788.

The first group contains the items chargeable to hydrography exclusively. The item magnetics is a small one, and this work being undertaken primarily for the mariner, it may properly be charged to hydrography.

The second group contains the items topography proper and triangulation, upon which it more immediately depends, *i. e.*, the secondary and tertiary triangulation. It does not include the primary triangulation nor the astronomical and base-measuring work upon which it depends, these latter being charged to the third group.

The third group is made up of the geodetic elements of the Survey, 79% of it being for triangulation. All of these items of expenditure, except the gravity experiments, are incurred for the purpose primarily of making accurate maps, topographic and cadastral, and secondly, or incidentally, of determining more accurately than we now know the size and shape of the earth. For these purposes the larger part of the cost is properly chargeable to topography.

The whole expenditure of $156 290 during the year 1889–90, called "party expenses," may therefore properly be charged against three classes of work, as follows:

Hydrography	46%	$71 900
Topography and the triangulation	31%	48 790
Geodetic work (including triangulation)	23%	35 600
Total party expenses		$156 290

This division of party expenditures we shall now assume to be a fair basis upon which to apportion the parts of the permanent salary list and miscellaneous expenses chargeable to the three groups of hydrography, topography and geodesy, and so doing, have this table:

	Party Expenses.	Percent.	Salaries.	Miscellaneous Expenses.	Total.	Area. Square miles.	Cost per square mile.
Hydrography...	$71 900	46	$108 330	$53 765	$233 995	5 314	$44
Topography....	48 790	31	73 005	36 233	158 028	839	188
Geodesy.....	35 600	23	54 165	26 882	116 647	.....	....
Total.....	$156 290	100	$235 500	$116 880	$508 670	.....	....

The cost of the topographic work executed in 1889-90 thus comes out $188 per square mile, which amount also includes the cost of engraving. This amount is probably somewhat too low, since a part of the cost of geodetic work should be charged to topography, and also because by reason of the service rendered by naval officers to hydrography, less than 46% of the salary list should be charged to hydrography.

These results are based on the single year 1889–90. They do not, however, differ much from those similarly derived for several years back.

The party expenses of the past seven years are shown in the following table. The classification is the same as that set forth for 1889–90. The percentage of expense chargeable to three great classes of work, viz., topography (including the smaller triangulation incident thereto), hydrography and geodesy, are $\frac{1}{3}$, $\frac{2}{5}$ and $\frac{1}{4}$.

PARTY EXPENSES (PERMANENT SALARIES NOT INCLUDED) OF THE UNITED STATES COAST AND GEODETIC SURVEY.

Fiscal years ending June 3d.	Triangulation and Topography.	Hydrography.	Geodesy.	Total.
1885	$66 797	$56 286	$40 953	$164 036
1886	67 768	72 240	45 334	185 342
1887	54 005	57 564	32 266	143 835
1888	57 070	64 569	35 489	157 128
1889	51 996	72 101	33 353	157 451
1890	48 789	71 909	35 592	156 290
1891	40 982	76 006	43 773	160 761
Sum	$387 407	$470 676	$266 760	$1 124 843
Mean	$55 344	$67 239	$38 108	$160 692
	34%	42%	24%	

These percentages afford, I think, the best means of judging the cost of the different classes of work in the past few years.

The work classed as geodetic is in the main made up of the two items, "Transcontinental Geodetic Triangulation," and "Furnishing Points to States," those items constituting about 70% of the whole. There is included precise leveling and telegraphic longitudes. As all these operations are primarily designed to form the foundation of a map of the whole country, and only secondarily and incidentally to

contribute to a better knowledge of the size and shape of the earth, this portion of the expenditure is properly chargeable to the cost of the map which is to be made. It should not, however, be charged to the cost of the maps into whose contribution it does not enter.

The average expenditure of the Coast Survey in the last eight years has been $509 000, and the average area topographically mapped has been 800 sq. miles per year. Of this amount expended, 34%, or one-third, has been used for the topography and secondary and tertiary triangulation connected with it. This yields an average cost of $212 per square mile.

This cost includes the engraving, but does not include any expenditure for the base measurements, astronomical work or primary triangulation. I regard an estimate of $200 per square mile as rather below than above the truth, and as entirely fair to the Coast Survey.

The estimates of the cost of the topographic work executed by the Coast Survey may therefore be summarized as follows:

Period.	Cost per square mile of—			Estimate made by—
	Triangulation.	Topography.	Total.	
1847.....	$13 95	$13 76	$27 71	Alex. D. Bache, Supt. C. S.
1864–68.....	343 00	241 00	584 00	Gen. C. B. Comstock, U. S. Engs.
.....	.....	12 to 97	.....	C. P. Patterson, Supt. C. S.
1858–72.....	120 00	283 00	403 00	Gen. C. B. Comstock, U. S. Engs.
1807–86.....	25 00	308 00	333 00	Capt. Geo. M. Wheeler, U. S. Engs.
.....	.....	.....	250 00	Hon. Hilary A. Herbert.
Recent years..	.....	.....	200 00	Marcus Baker.

Map of the District of Columbia.—A topographic map of the District of Columbia was begun in 1881 by the Coast Survey in conjunction with the Engineer Office of the District of Columbia. The scale adopted was 1:4800, or about 13 ins. to 1 mile, and the contour interval, 5 ft. The party expenses were specifically provided for in the District of Columbia Appropriation Bill, which for the 11 years, 1881 to 1891, inclusive, appropriated annually an average sum of a little less than $6 000.

The land area of the District of Columbia is 60 sq. miles, of which 11.8 sq. miles lie within the original limits of Washington and Georgetown, and were not included in the survey. Hence, the survey covered 48.2 sq. miles, and for this area the party expenses amount to $65 600, or $1 361 per square mile.

In the experience of the Geological Survey, party expenses constitute one-third of the cost of the finished manuscript map. There is little departure from this ratio in a rather extensive experience. If the same ratio applies in Coast Survey experience, then the cost is $4 083 per square mile, or $6 40 per acre. Assuming, however, that salaries of the officers and surveyors who did this work were only just equal to the party expenses, the cost would be $2 722 per square mile. The data for a close estimate are not at hand, but I am of opinion that the cost of the manuscript map of the survey will be found not less than $3 000 per square mile, or nearly $5 per acre.

The appropriations for this work, made by Congress, 1881–91, were "for surveys of the District of Columbia with reference to the future extension of various avenues to the district line," and are as follows:

Fiscal year ending June 30th.	Appropriation.	Reference.
1881	$5 000	United States Statutes at Large, Vol. 21, p. 156.
1882	5 000	" " " " 21, p. 458.
1883	5 000	" " " " 22, p. 135.
1884	5 000	" " " " 22, p. 464.
1885	5 000	" " " " 23, p. 125
1886	5 000	" " " " 23, p. 313.
1887	4 000	" " " " 24, p. 132.
1888	4 000	" " " " 24, p. 573.
1889	10 000	" " " " 25, p. 319.
1890	10 000	" " " " 25, p. 799.
1891	7 600	" " " " 26, p. 298.
	$65 660	

SUMMARY OF THE COST OF TOPOGRAPHIC SURVEYS IN THE UNITED STATES.

	Area. Square miles.	Cost.	Cost per square mile.	Scale of manuscript map.
United States Geological Survey	583 922	$2 496 776	$4 27	1 : 125 000 1 : 62 500 1 : 45 000 1 : 30 000
New Jersey	7 894	54 744	6 93	1 : 21 120
Massachusetts	8 315	107 800	12 97	1 : 30 000 and 1 : 45 000
Rhode Island	1 085	9 733	8 97	1 : 45 000
Connecticut	5 004	48 999	9 79	1 : 45 000
Perkiomen Water Basin	446	.....	145	1 : 4 800
Mississippi River Commission	1 954	99 930	51	1 : 10 000
United States Lake Survey	.....	.....	125	1 : 10 000
United States Coast Survey	.....	.....	200*	1 : 10 000 and 1:20 000
District of Columbia	48.2	.....	3 000	1 : 4 800

* Publication included.

Mr. HERBERT G. OGDEN.—Mr. Allen's remarks are a valuable contribution to this subject, in giving us some definite data on the cost of several surveys for special purposes, and especially in the details of the errors of closure in work of this kind; information, it seems, very difficult to obtain. Such information bears directly on the recommendation that some rules, or a criterion, should be established, by which the results of topographic surveys should be gauged, and I am exceedingly pleased that he approves of the suggestion. I wish that he might go further, and, indeed, that all civil engineers would take an interest in the subject, and express themselves personally and through their societies on this important question of a criterion, particularly in the details, specifying the degree of accuracy that should be required to render general topographic work, that could be obtained within a reasonable cost, of the best quality for engineering purposes.

Mr. Gannett's statements would have been of more value to us if he had specified the degree of accuracy that is obtained in the work conducted under his direction. We may all be quite agreed that certain features should be represented; but how accurately they should bear their true relations to each other has often been in dispute and still seems far from settlement. It is far from satisfactory that Mr. Gannett should ask "how the errors of a map are to be determined absolutely, since any work done to test the map is itself liable to error." Indeed, this would imply that the degree of accuracy attained in his own work has not yet been fully ascertained. That "two surveys of the same ground will only serve to illustrate the differences between the surveys," is a statement that will hardly be accepted by surveyors. Mr. Allen has shown us how work under his cognizance has been checked, and I am quite sure, as he suggests, that any statement on the face of a map that will explain the methods that were employed in making the survey would convey to the great majority of engineers the degree of accuracy in the completed work, provided, of course, they have confidence in the fidelity of the surveyor who executed it. But a re-survey is never necessary to determine the accuracy of a piece of work; an instrumental examination can always be made, covering large areas, in a very short period, that will develop the general reliability of the map. No more is it necessary that we should know the height of a hill to be sure that our survey has determined it within 5 ft., for experience has demonstrated that certain

instruments carefully used will produce certain results; and in all surveys there are more or less opportunities to bring checks on elevations, as well as distances, that we know from experience must determine the results within well-defined limits. Mr. Allen's example is a very happy one, but will any of us believe that if his distances had been measured by an odometer, his directions by a compass, and elevations by an aneroid barometer—the method followed in much of the traverse work of the Geological Survey*—that his work would have checked as he has represented? Mr. Gannett admits that checks are available in some descriptions of work; we have only to specify what discrepancies should be permitted in using these checks for distances, and establish like rules for elevations, to form a reasonable criterion.

I have already stated that it is impracticable to prepare an estimate of the average cost of the topographic work of the Coast and Geodetic Survey, although many attempts have been made to do so. The figures presented by Mr. Gannett, about $200 per square mile, are doubtless derived from the estimates recently prepared by his associate, Mr. Marcus Baker. Estimates of a similar character were presented by General Comstock some years ago, placing the average cost at something over $400 per square mile. More recently, Captain Wheeler found $330 more nearly correct; and now Mr. Gannett presents revised figures, reducing the sum to $200. I sincerely trust our friends who are interested in this matter will continue their figuring in the hope that eventually it will bring the price down to something that can at least be admitted as an approximation. We know very well the cost of many individual pieces of work; those to which I have referred represent the cost of areas that have been among the most difficult and expensive; and an estimate, therefore, of the average cost of the topography of the Coast Survey that is more than twice as great as these individual instances cannot have much reliance placed upon it.

These excessive estimates for the cost of Coast Survey topography are largely due to the methods employed in preparing them, much more to this cause than to the details of the operations Mr. Gannett has referred to, though doubtless the production of accurate work is more expensive than work of a lower grade. They have uniformly

* Report of Superintendent, Coast and Geodetic Survey, 1891, Appendix 16, page 708.

been based upon an assumption that in the total expenditures for the Survey the cost of triangulation, topography and hydrography must have been incurred in fixed ratios to the whole amount, and that all the expenditures for the Survey are properly chargeable to one of these classes of work. This assumption ignores the fact that large sums are expended annually in the maintenance of published work, the publication of results, support of plant, executive work, special surveys, re-surveys and examinations, and similar operations that do not pertain to the three principal classes, but, having been included in these estimates, render the ratios worthless. To put figures derived from such sources beside those from the Geological Survey, which embrace only the completion of the manuscript map, or beside those for the State surveys of Massachusetts or New Jersey, which go no further, and also omit the cost of triangulation, is calculated to mislead and would vitiate any estimates that should be based upon them.

The field work of the topography of the Coast Survey is so involved with expenditures for triangulation and hydrography, executed by the same parties and paid for on the same rolls, that it is impossible to separate the charge for topography from other expenditures; but even if we could do so, the cost of the narrow strip of work embraced in our operations would not be a guide, and could hardly be used in estimating the cost of topographic work away from the coast, since the details of shore-line, islands, ledges, rocks and low water that are represented on our sheets, besides the difficulty and great expense incident to maintaining field parties on many sections of the coast, necessitate expenditures greatly enhancing the cost and that would not be incurred on plain interior work.

Mr. Gannett's estimates for the time required to survey the whole United States are unique, and might be used for an argument if they were based upon correct premises. Unfortunately for the argument, however, he has interpreted my statement that the cost of topographic work would not exceed $35 or $45 per square mile for the most difficult and detailed areas as an estimate for the average cost per square mile. I regret that he should have so misunderstood my plain statement, as it involves him in a computation that runs forward to the year 2373 A. D. In point of fact, the suggestions I made were to accomplish the survey in a generation, which is even a shorter time than is now claimed would be necessary to complete the topographic

work of the Geological Survey. Joint work by the National Government and the States would in a very few years permit a moderate assistance to all the States, and certainly, if all the States were engaged at once in making surveys within their own territories, we would hardly anticipate a delay in the final results of 480 years, or even 50 years. But all estimates predicting the time within which such a great work can be accomplished are tentative and subject to modification by changes occurring in the future, and over which we have no control; and I look, therefore, upon estimates of this character as very largely a waste of time. In 1856 the Superintendent of the Coast Survey estimated that, at the rate of progress then being made, he would complete the original surveys of the Atlantic and Gulf coasts in about 12 years. The estimate was doubtless correct if all things had remained equal; but our Civil War was soon an interruption, and subsequently the necessity for re-surveys and the demand for more rapid extension in more important localities necessitated deferring a large part of the work on the Atlantic and Gulf coasts, that the forces available might be utilized in these other more important localities, and, consequently, the original surveys can hardly be said to be completed to-day. Another instance of the unreliability of such estimates can now be found in the Geological Survey. In 1885 Major Powell, the Director, stated that at the rate of progress of his work at that time he estimated that he would be able to complete the geological map of the United States, exclusive of Alaska, in a period not longer than 24 years;* but now Mr. Gannett estimates that the topographic work alone will require twice that period of time, and from one of Mr. Baker's tables I find that the average cost per square mile for this topography has been increased from $4.27 for 11 years to $6 for the last three years, and to $9.58 for the year 1893. If the estimates of the Geological Survey are to increase at this alarming ratio, we may well fear that the year 2373 A. D. will overtake even that progressive organization before it has completed the topographic survey, and that $120 000 000 will be a mere bagatelle in comparison with the actual cost.

Mr. Baker has restricted his estimates of the cost of the field work of the Coast Survey to the seven years since 1885. For reasons which

* Public Documents—Senate, 49th Congress, 1st Session, Miscellaneous Documents No. 82, pages 20 and 42.

I have before outlined it is impracticable to ascertain the exact cost of any branch of the work, even for this brief period; but an approximation could doubtless be arrived at by a thorough inspection of the accounts; this would prove or disprove Mr. Baker's statements. But for the present purpose it will be quite sufficient to show that he has fallen into a very serious error, which will, at least, prove the negative. An endeavor to divide the work into three classes for the past few years, with sufficiently complete data before him to show the nature of the expenditures, is a serious mistake that seems to be hardly justifiable in preparing an estimate that was to be compared with the cost of other surveys which include no expenditures beyond the manuscript map, as shown in his final table of the cost of different surveys in the United States; but he has committed a much more marked oversight in charging all the expenses of the subsidiary triangulation to topography, for his experience as an officer of the Coast Survey for a number of years should certainly have taught him that triangulation is as essential in the execution of hydrographic work as it is in topographic work. The percentages, therefore, that he presents are entirely untrustworthy. If we should transfer to hydrography one-half of the expense of triangulation that he has allotted to topography, it would reduce his final estimate of the cost of topographic work about 24 per cent. What further reduction would be made by allotting expenditures to the various classes to which they should properly belong I am unable to say, and must leave Mr. Baker or some other kind friend the task of ascertaining.

The detailed survey of the District of Columbia was conducted jointly by the city government and the Coast Survey, and I am not aware that the total expenditure has ever been compiled, although there should be no difficulty in ascertaining the fact if required. I have already described the work, but may as well lay stress here on the fact that the elevations are determined with the same precision as the linear distances; and in view of the cost of all detailed work of this character of which we have any record, in which both the horizontal and vertical distances have been determined with absolute precision, I do not believe that even the estimate presented by Mr. Baker, for $5 per acre, would be excessive. In Appendix 16 of the Coast Survey Report before referred to are two letters from Mr. J. C. Olmstead, in which he gives the cost of a number of special surveys for park im-

provements and similar purposes, and in which he concludes "that the fair, ordinary cost for a quality of survey such as suits our purposes is generally about $5 per acre." But he states that such surveys range from $2.50 to $20 or more per acre, the larger price, of course, including much greater detail, such as shrubbery, boulders, etc.. that may appear upon the surface. Statements of cost, to be intelligible, should embrace statements of the accuracy of the work with them, for the greater cost is usually entailed by greater accuracy. The appearance of the map is not always a safe guide to a judgment of its value, and I deprecate all comparisons that do not explicitly set forth the degree of accuracy the work represents.

Let the engineers in the country determine the character of the work that will best subserve general purposes, and we may be assured that legislators and those interested in the general welfare will appreciate their efforts and assist in securing its accomplishment.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

677.

(Vol. XXX.—December, 1893.)

THE USE OF LONG STEEL TAPES.—DISCUSSION ON PAPER No. 636.*

By ROBERT MOORE, CHARLES B. BRUSH, J. A. OCKERSON, O. B. WHEELER and H. M. MARSHALL.

ROBERT MOORE, M. Am. Soc. C. E.—I can give an incident from my own experience in regard to the use of steel tapes which I now use for all classes of work in preference to anything else. Some years ago, when it became necessary to construct the elevated line of the Merchants' Bridge Terminal, the railroad company undertook to place the foundations on which the superstructure was afterwards to be placed, and it became necessary to so locate them that the superstructure would go on without any misfits? I sent to the Phœnix Bridge Company, who were making the superstructure, and asked them to send me a steel tape which was accurately compared with their standards. In reply they told me that it was not their practice to make accurate measurements with steel tapes at all; but that they used wooden rods. So in place of the steel tapes they sent me some wooden rods which were accurately compared with the standard in use in their

* "Recent Experience on the U. S. Coast and Geodetic Survey in the Use of Long Steel Tapes for Measuring Base Lines." By R. S. Woodward, C. E. *Transactions*, Vol. XXX, page 81.

shop. I instructed the assistants to use these rods on the work. They reported, however, that, owing to the difficulty in making and maintaining perfect contact between the rods, their work did not check up as well as with the steel tape, and requested my permission to lay the rods aside. This was accordingly done, and the steel tape only used in placing the several thousand anchor bolts which were necessary in this structure. The results were entirely satisfactory, as in placing all the spans there was not a single misfit due to any failure in placing the anchor bolts. I am satisfied there is nothing superior to the steel tape for all purposes of engineering work.

CHAS. B. BRUSH, M. Am. Soc. C. E.—The foundations of all the structures for the North Hudson County Railway Company in New Jersey were located with steel tapes. There was no difficulty. The results obtained were satisfactory.

J. A. OCKERSON, M. Am. Soc. C. E.—In August, 1880, a base line for secondary triangulation was measured by the writer with a 300-ft. steel tape. This is thought to be the first secondary base measured with a long steel tape in this country. It was measured as an initial base for the secondary triangulation of the Mississippi River.

This base line is situated in Missouri, opposite the mouth of the Illinois River. It was 6 663 ft. long and level from end to end.

A constant and uniform tension in the tape was obtained by a fixed weight hung over a pulley.

Only one thermometer was available, hence only one was read. The tape was supported on the tops of stakes 1 in. wide at intervals of 25 ft. The stakes on which the marks were made were entirely detached from the straining stakes.

Two measurements were made under a bright sun with an average temperature of 94° Fahr. 2 ft. from the ground, and 123° with the thermometer lying on the ground.

Each measurement occupied nearly four hours, and the discrepancy in the two measurements was 1 in 73 000.

In 1891, a base was measured at New Boston, Ill. Length of base, 18 066 ft. Average time required for each tape length, 2.2 minutes. Discrepancy between first and second measurements, 1 in 759 000. The measurement was made before sunrise.

In 1892, a base line was measured at Rapids City, Ill. Length of line, 5 624 ft. Time required for first measurement, 41 minutes; second,

28 minutes. Discrepancy between first and second measurements, 1 in 594 917.

In 1893, three secondary base lines have been measured, viz.: At East Dubuque, Ill., length, 7 105 ft. Time required for first measurement, 68 minutes; second, 53 minutes. Discrepancy between first and second measurement, 1 in 346 965.

Cassville, Wis., length, 7 001 ft. Length of time of first measurement, 47 minutes; second, 37 minutes. Discrepancy between first and second measurements, 1 in 266 412.

Prairie du Chien, Wis., 5 312 ft. long. First measurement made in 45 minutes, second in 35 minutes. Discrepancy between first and second measurements, 1 in 265 000.

None of these measurements were made in the sun.

The tape used in the above measurements, except the first, is 300.03851 ft. in length with a tension or pull of 16 lbs. at a temperature of 62° Fahr., and supported at intervals of 30 ft.

The dimensions are 0.0246 by 0.1225 in.; area of cross-section, 0.003014 sq. in.

The tape was made by Buff & Berger.

The preparation of a base line one mile long requires about 500 ft. of lumber for supporting and straining stakes. It requires the labor of six men for about two days, to clear the line, set the stakes, and establish the grades. The measuring is best done with one man at each 30-ft. length, one marker and one helper at the rear end, one marker and two helpers at the front end, and one man at each of three thermometers, or a total of 16; a much smaller number could do the work very well.

In the survey of the Mississippi River, the results obtained with the long steel tape have been highly satisfactory, and the small cost of a line measured in this way makes it practicable to use more lines and thus materially reduce the magnitude of the errors in a chain of triangulation by having more frequent checks. It has therefore been decided to have base lines at intervals of about 25 miles or about 12 triangles apart.

In the enumeration of base lines given above, the figures are only given in round numbers, as the final reductions of some of them have not yet been made.

With proper appliances and careful manipulation a high degree of accuracy can be attained with the steel tape, and it should be adopted

without hesitation for all base lines, except a very few standard primary bases to be used as initial and final check lines.

The important thing is the correct temperature of the tape. The latter is very sensitive and responds to changes of temperature more quickly than the ordinary thermometer.

O. B. WHEELER, M. Am. Soc. C. E.—Our use of the long steel tape under the Missouri River Commission has been to transfer, as it were, a carefully measured base line to other parts of the country. In other words, we standardize our steel tape by measuring a primary base line by the same method and apparatus that we use in measuring a new base line. By measuring at night we get a good control of the temperature disturbance. I have long believed that a base line can thus be transferred with all sufficient accuracy for any system of primary triangulation, since the extreme accuracy of a measured primary base line is soon lost through the angle measurements.

It is proper, perhaps, to discard the friction hooks, especially if the standardizing is done without their use, but I think the automatic "stretcher" or "adjuster" should not be discarded. Autometry is more in the line of progressive science. The "adjuster" as used by us, and described and illustrated in the report of the Missouri River Commission for the year 1886, consists, in principal, of equal lever arms joined at an angle of 90° in a knife-edge bearing at the juncture. The horizontal arm carries the weight and a spirit-level, while to the vertical arm the tape is attached. The bearing for the knife-edge is on a platform upon posts, and is controlled by slow-motion screws.

The exact pull to a small fraction of an ounce is found by placing the weight upon a platform scale, while its support is fixed in its proper place on its arm, the knife-edge being in its bearing and the level showing that the horizontal arm is horizontal. The rear end of the tape is fixed to a stretching post, and controlled also by a slow-motion screw.

In measurement, in moving forward, the "adjuster" is rapidly dissected, and as great rapidity is obtained as that shown in the paper under discussion. It is possible also to eliminate the "lag of thermometers," when measuring during a continuous fall (or rise) of temperature, by measuring in the reverse direction, the rear end of the tape becoming the forward end, to obviate the necessity for more platform stakes.

To prevent as much as possible the disturbance by wind, dew and dust, I would recommend a much lighter or narrower tape. The piano wire, as used by Professor S. W. Robinson in 1873, is the ideal, only that the flat wire is preferable to the round, that any twist may be detected.

I am happy to have it demonstrated that the long steel tape is applicable for the measurement of the primary base line, and I would suggest that if ever the arcs of meridian in distant countries are to be remeasured, that the base lines be measured with this easily transported apparatus.

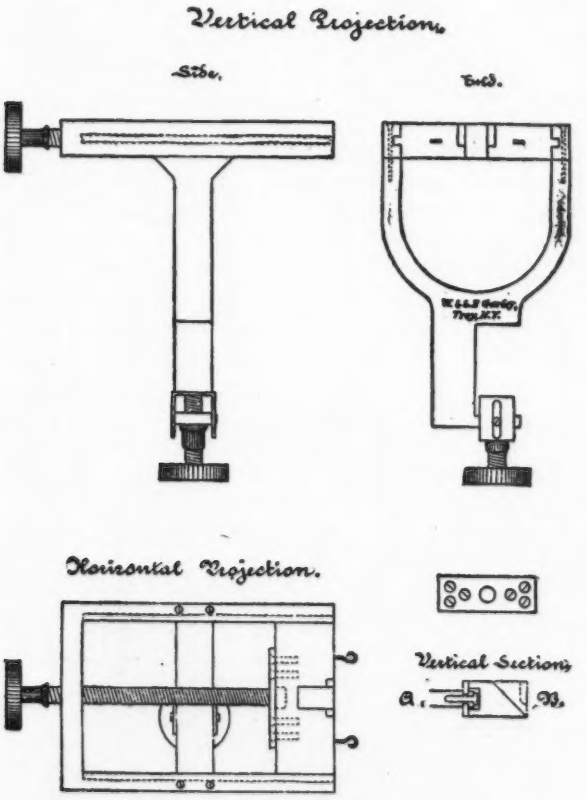
H. M. MARSHALL, M. Am. Soc. C. E.—Professor Woodward has added very strong evidence as to the efficiency of long steel tapes in base measuring, and, as imitation is the sincerest flattery, he has testified his highest appreciation of the good work done on the Mississippi and Missouri Rivers down to the minutest detail. The ice-packed bar proposed by Mr. E. S. Wheeler, the zinc plate of Mr. O. B. Wheeler, and the spring balance of Professor J. B. Johnson, all come in for commendation. It is, however, a little surprising that he failed to use the wire hooks on the nails to support the tape, for they would have saved using the tape after the fashion of a score line to adjust the friction.

In the year 1889, when triangulation was begun on the Red River Survey, it was not considered necessary in the U. S. Engineer Office at Vicksburg to make any particular investigation as to the accuracy to be attained in measuring bases with steel tapes. This was partly because a small tertiary system had to serve for practical purposes of the work, a secondary triangulation being contemplated only in the dim future; and partly because, being a branch of the public service somewhat connected with the river commissions, their experience was quite acceptable at its face value.

With the value of the method proven, only improvement in the details of the appliances was to be desired. Mr. O. B. Wheeler's apparatus used on the Missouri River to apply tension was as much preferable to that on the Mississippi River as a steel yard is to a spring balance in weighing, and only needed to be made of metal to be perfect. This was done, as shown on pages 643 and 644, and described as follows:

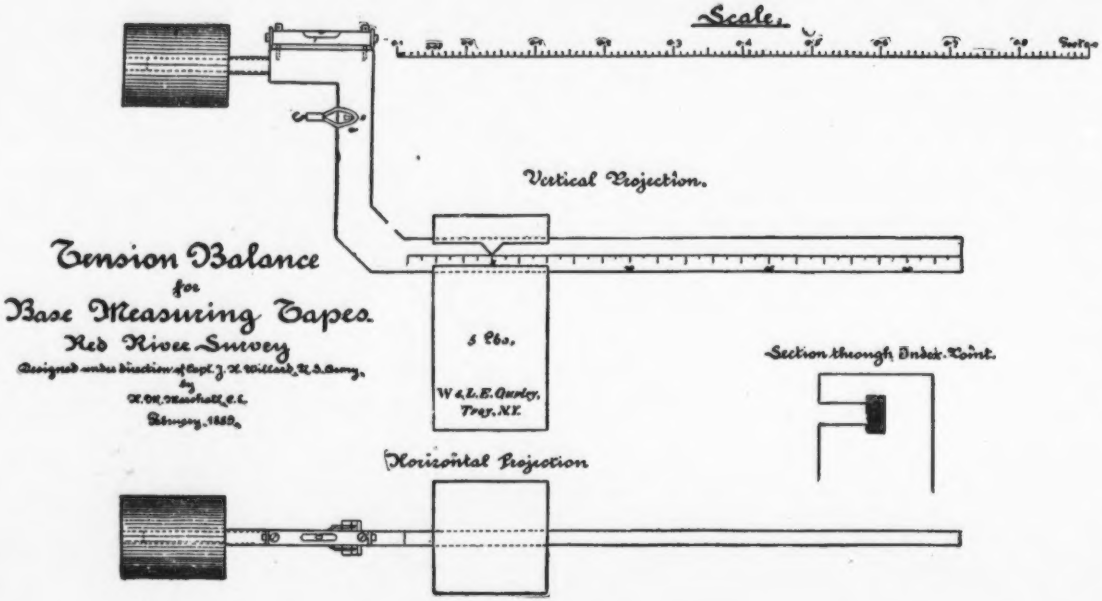
(1) Four tension frames.

(2) Two balance beams.



Tension Balance
for
Base Measuring Tapes,
Red River Survey.
Designed under direction of Capt. J. N. Willard, U. S. Army,
by
O. Dr. Marshall, C. E.
February, 1889.

Scale.


Scale.
Vertical Projection.
Tension Balance
for
Base Measuring Tapes.
Red River Survey
Designed under direction of Capt. J. N. Willard, U.S. Army,
by
W. M. Haskell, C.E.
February, 1869.
5 Lbs.
W. & L. E. Gurley,
Troy, N.Y.
Section through Index Point.
Horizontal Projection

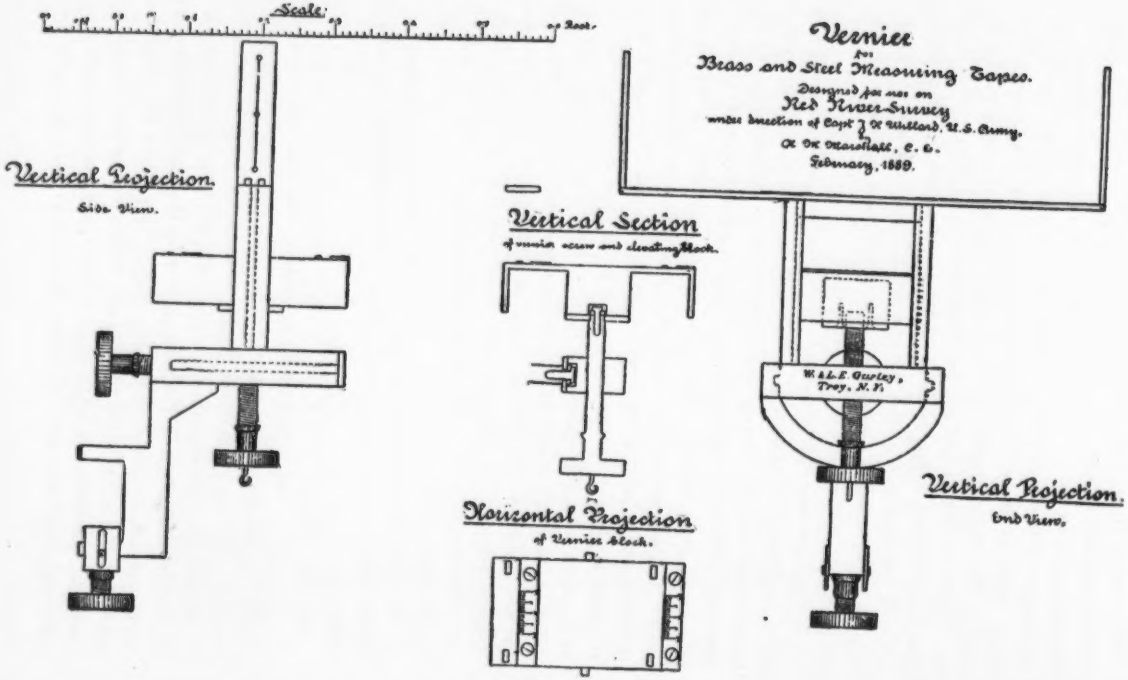
The tension frame consists of a clamp and frame of brass shown in vertical projection side and end and horizontal projection, page 643 The clamp has two arms above it, to which is screwed the three-sided rectangular frame. A screw working in one end moves the brass block, which is guided by flanges sliding in grooves in the sides of the frame. The screw is attached to the block, as shown in section A B, by a collar, so that it will not be disengaged by turning. Two small hooks are screwed in the front of the block, to attach the tape-chains when the frame is used at the rear end of the tapes. A triangular space is cut out of the block, and in the sides adjacent are cut seats for the knife edges r of the balance beam to rest in.

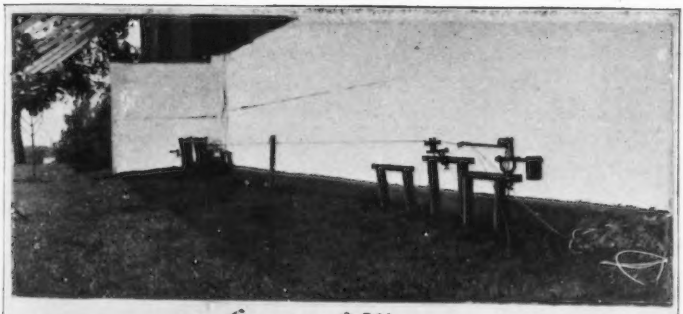
The balance beam, shown in side view, and projection, page 644, is brass, and has steel knife-edges r on which it rests, and knife-edges s, about which turn the stirrups of the steel hook to which is attached the front end of the tape-chain. On top of the upper short arm of the beam is a small level vial in a case attached by adjusting screws to the beam. On the end of this short arm is a screw on which works a counterpoise, to balance the beam without the pea. The long arm of the beam is divided, so that the mark 5 is the same distance from the knife-edges r, on which the beam rests, as are the knife-edges s, about which the stirrups turn, and indicates a tension equal to the weight of the pea, and twice that distance a tension twice the weight of the pea. The pea weighs 5 lbs., and its mass is so distributed that the center of gravity lies in a vertical plane perpendicular to the face through the index point.

The method of marking tape ends was not considered satisfactory, and in lieu of pieces of zinc two verniers were substituted, as shown on page 646.

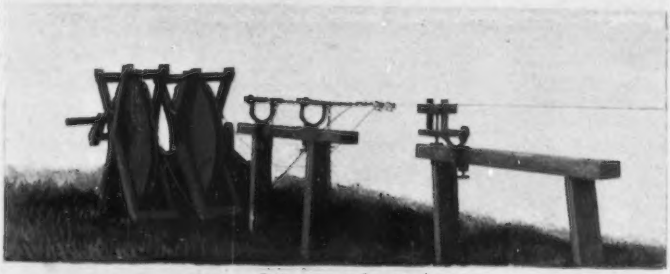
(3) Two verniers.

The vernier, shown in vertical projection, side and end views, also vertical section and horizontal projection of the vernier block (page 646), consists of a clamp and frame similar to the frame of the tension-balance, with the addition of a hollow cast-block. This block is attached to a slow-motion screw for raising it under the tapes after they are stretched, and is guided by flanges sliding in grooves in two vertical arms fastened to the other brass block, which is capable of transverse motion. The hollow cast-block has on its upper face two metal graduated strips laid flat, with stops near the ends, to hold the tapes close

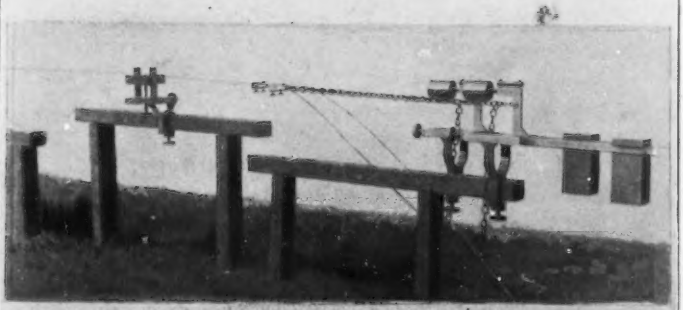

Scale.
Feet.
Vernier
for
Brass and Steel Measuring Tapes.
Designed for use on
Red River Survey
under direction of Capt J. N. Willard, U.S. Army.
by Dr Marshall, C. E.
February, 1889.
Vertical Projection.
Side View.
Vertical Section
of vernier screw and sliding block.
Horizontal Projection
of Vernier Block.
W. & L. E. Gurley,
Troy, N. Y.
Vertical Projection.
End View.



General View



Rear End



Front End

to the vernier. Verniers are marked 0 at the middle and are set exactly opposite. The graduation extends 9 mm. each way from the zeros, and is divided into ten parts, so that the reading is to 0.1 mm. In the grooves of the vertical arms slips a flange fastened to a bar carrying folding compass-sights, which enables the vernier zeros to be brought at right angles to the base line. In the center of the head of the vertical slow-motion screw is a small hook for attaching a plumb bob.

These verniers do not admit any referring in the future to the observations except through the record, and neither does a transit, to the angle measured by it; but, like the transit, the verniers permit independent measurements to be repeated at will. The apparatus was made by W. & L. E. Gurley, and is contained in a box 10 x 14 x 20 ins., the whole weighing about 40 lbs. The tapes—for it was designed to use a steel and brass tape—were made to order, a little more than 100 m. long, 3½ mm. wide, and one-tenth as thick. The breaking load of the brass tape is 96 lbs., and of the steel, 387 lbs., by tests made at the Watertown Arsenal. The graduation was done in the U. S. Coast Survey shops at Washington, in November and December, 1889, the steel tape being copper-plated at the ends to receive the engraving. This graduation extends both ways; from the standard marks near the tape ends over a space of 2 dcm. divided to millimeters. The numbering runs both ways from the zeros at the standard marks. The tapes are kept and transported on reels about 15 ins. in diameter, made like sheaves with ⅜-in. opening, turning in a frame by a crank and handle. This is not quite satisfactory, and they will be wound on drums.

Measurements were conducted in the usual way, excepting alterations brought about by the use of the verniers. The programme is as follows:

Beginning at the rear end of the tape, two stakes are driven about 3 ft. back of the initial point of the base. On top is nailed a piece of plank, which makes a table to clamp tension frames to, one on each side. Two stakes are next driven level with the first two stakes, but 2 ins. to the right of the line, about 9 ins. forward and back of the initial point of the base. On these is nailed a plank for clamping the vernier. Along the line, at intervals of one-tenth the tape length, stakes are set, with nails driven in the rear face of the stake, the heads being a little lower than the points; the nails are kept about level by the eye. At the front end of the tape, stakes are set for tables, as at the rear end; and in addition a table is set on line about 3 ft. forward of the end of the tape and 2½

ins. lower than the vernier table, for clamping the tension frames o. the balance beams. Elevations are taken on the vernier tables and heads of nails with a level. An observer, a recorder, and one assistant at each end of the tapes, and nine men at intervals of one-tenth the tape length, place the tapes one on each side of the stakes supported by the suspension hooks hung on the nails. The assistants adjust the clamps near the tape ends, and hook on the chains, clamp the tension frames to the straining tables, one on each side, and by means of the chains attach the rear ends of the tapes to the frames and the front ends to the hooks on the balance beams, rest the beams on the knife-edges, and slip the pea on the beam and set it to the required pull ; adjust the tension by the slow-motion screws of the frames till the beam is balanced and the level centered. The observers clamp a vernier to the table at each end of the tape. At the rear it is set by the plumb over the initial point, aligning by the compass sights, raised under the tapes by the elevating screws, and adjusted by the transverse screws till the tapes lie easily alongside the verniers. With pocket rule the rear observer measures the height of the vernier above the table. The observer at the front end cries, "Ready! Read steel!" Both read the distance in millimeters on the tape from its zero to the vernier zero and tenths of a millimeter on the vernier, and have the recorders make the entry. The observer at the rear end replies, "Read!" The observer at the front end cries, "Read brass!" Both read as before, and the observer at the rear end replies, "Read!" The front observer cries, "Shift tapes forward!" and assistants by means of the slow-motion screws move the tapes bodily several centimeters along their length, the men at intermediate stakes being careful to keep the supporting-hooks swinging free by tapping them lightly. The front observer again cries, "Ready!" and the operation is repeated. The tapes are then shifted back beyond the initial reading, and readings taken again.

In the reduction the mean of all the readings for each tape is taken to obtain the distance between vernier zeros.

For the next tape length the front observer calls out "Make ready!" the assistant at the front end lifts the balance-beams and slips off the peas, both assistants unhook chains and unclamp tension-frames, men along the line lift tapes and suspension hooks, the rear observer unclamps the vernier and sends it forward by his recorder to the front recorder, the front observer leaves his vernier clamped and calls "Forward, march!" The remaining part of the base is measured in the

same way, except that after moving forward the rear observer does not change the position of his vernier, unless he may have to alter the elevation by the elevating screw. In reading and recording, forward is counted from the tape zero in the direction the base is measured. At the front end of the tape, forward readings are plus, and backward readings are minus. At the rear end, forward readings are minus, and backward readings are plus. The check on readings in the field is that the first reading at front end minus the second reading at the front end must be nearly equal (within 0.5 mm.), the first reading at the rear end minus the second reading at the rear end, and must be of opposite sign; in other words, after the tapes are shifted, the shift must show the same amount and of opposite sign at the two ends of the tape; otherwise the readings are wrong.

To ascertain the length of the tapes, the Coast Survey base at Delta, La., was measured with the steel tape alone, on three nights in April, 1889. This base had been measured by means of 6-m. contact slide rods by the U. S. Coast and Geodetic Survey in 1878, and the length between monuments was furnished Captain J. H. Willard in manuscript by especial request for our purpose. The following table shows the field record on the first night for the first half dozen tape lengths:

DELTA BASE.

Observations for Standardizing Steel Tape—April 9th, 1889.

FRONT END.

Tape No.	Reading. Forward. +	Reading. Backward. −	Thermometer No. 2.	Time.	Mean reading.	Remarks.
	Millimeter.	Millimeter.	Degrees.	P. M.	Millimeter.	
1...	67.1	.....	66.1	8.22	+27.7	T. C. Thomas, observer. W. H. Polk, recorder.
	4.6	.....	68.0			
	11.3	.....	68.4			
2...	39.1	.....	66.8	8.40	+41.2	Thermometer No. 2. At 70 m. from rear end is U. S. Signal Service compared thermometer No. 791.
	32.0	.....	66.9			
	52.8	.....	66.5			
3...	2.8	.....	63.1	8.57	+7.7	
	3.1	.....	63.1			
	17.1	.....	62.5			
4...	.....	1.3	60.2	9.23	+0.6	
	1.5	.....	58.2			
	1.5	.....	58.1			
5...	43.9	.....	60.0	9.50	+35.4	
	36.4	.....	59.6			
	25.9	.....	59.3			
6...	49.7	.....	57.8	10.04	+58.8	
	59.5	.....	57.7			
	67.2	.....	57.7			

REAR END.

Tape No.	Reading. Forward. +	Reading. Backward. −	Thermometer No. 1.	Time.	Mean reading.	Remarks.
	Millimeter.	Millimeter.	Degrees.	P. M.	Millimeter.	
1...	19 3	.....	68.0	.....	+19.4	T. G. Rombauer, observer. C. H. Schermerhorn, recorder.
	.....	42.0	67.8			
	.....	35.5	68.8			Vernier above table 71 mm.
2...	26.0	.....	68.5	.....	−28.6	Thermometer No. 1. At 30 m. from rear end is U. S. Signal Service compared thermometer No. 1522. Vernier above table, 64. mm.
	20.0	.....	68.8			
	39.8	.....	68.8			
3...	.....	8.8	64.3	.....	+4.1	Vernier above table, 70 mm.
	.....	8.7	64.3			
4...	5.3	.....	64.9	.....	−14.1	Vernier above table, 57 mm.
	14.1	.....	63.3			
	14.1	.....	62.1			
	14.2	.....	62.8			
5...	9.3	.....	61.0	.....	+0.8	Vernier above table, 70 mm.
	1.8	.....	60.9			
	.....	8.7	60.8			
6...	14.3	.....	59.0	.....	−22.8	Vernier above table, 57 mm.
	23.5	.....	59.0			
	30.7	.....	58.9			

The tape length was evaluated from the three nights observations, by use of the formula—

$$L = \frac{B + \frac{\Sigma h^2}{2l} + \frac{\Sigma h^4}{8l^3} - \Sigma (s + s^1).}{n + e\,\Sigma t}$$

in which B is the length of the base, h and l the difference in height and distance between supports, s and s^1 the readings at the front and rear ends of the tape, n the number of tape lengths, e the coefficient of expansion of the tape, and t the temperature, Fahrenheit, minus 60°.

The relative lengths of the steel and brass tapes were ascertained by 51 simultaneous readings of the two tapes stretched side by side, at various times under 16 lbs. tension, and supported as in measuring a base, the temperature varying from 40.4 to 88.° Fahr.

The result of each observation being written in the general form—

$$t = \frac{L - L_1 - (b + b^1) + (s + s^1)}{e_1 L_1 - eL}, \text{ or}$$

$$t\,(L_1 e_1 - Le) = L - L_1 + [(s + s^1) - (b + b^1)]$$

putting $y = (s + s^1) - (b + b^1)$; $x = t$; $a = L_1 e_1 - Le$; $c = L - L_1$ the equation becomes $ax = c + y$.

When x and y are taken as the mean of all the observations

$$c = ax_o - y_o$$

and taking the difference between the mean and each observation

$$a\,(x - x_o) - (y - y_o) = 0.$$

By multiplying through by $(x - x_o)$, that is, giving servation weight according to its range in temperature,

$$a\,(x - x_o)^2 - (x - x_o)\,(y - y_o) = 0.$$

Summing the results of all observations,

$$a\,\Sigma\,(x - x_o)^2 - \Sigma\,(x - x_o)\,(y - y_o) = 0$$

$$a = \frac{\Sigma\,(x - x_o)\,(y - y_o)}{\Sigma\,(x - x_o)^2}$$

L_1, e_1, b and b^1 being the length, coefficient of expansion, and readings of the brass tape. The length of the tape being known, the length of a base is given by the formula—

$$B = n\,L + e\,L\,\Sigma\,t - \frac{\Sigma\,h^2}{2l} - \frac{\Sigma\,h^4}{8l^3} + \Sigma\,(s + s^1)$$

and the temperature by the formula—

$$\Sigma\,t = \frac{n\,(L - L_1) - \Sigma\,(b + b^1) + \Sigma\,(s + s^1)}{e_1 L_1 - e\,L}$$

When $L = L_1$

$$\Sigma\,t = \frac{\Sigma\,(s + s^1) - \Sigma\,(b + b^1)}{(e_1 - e)\,L}$$

To check the length of the steel tape, as determined at the Delta base, measurement was made of the U. S. Coast and Geodetic Survey base at Lum Point, La., during nights in February, 1892. The length between monuments was furnished again in manuscript with that end in view. This base was not commensurable with the tape, and 3.75 m. were deducted by measuring back with a precise level rod, and the remaining portion measured with the steel tape. The length of the base as measured by the tape was 1 921.8223 m., and was given by the Coast Survey 1 921.823 m. To get a further independent check, the base was extended five tape-lengths, using the tape as short as possible; that is, with the scale readings all minus, and then base and extension were measured as one, using the tape as long as possible. Two measurements were made, and while the mean is quite close to the first determination, the range is wide.

The following results serve to show the discrepancies in the several measures:

DELTA BASE.

April 9th, 1889	$27\,L + 92.1$ mm.
April 10th, 1889	91.7 "
April 11th, 1889	91.3 "

LUM POINT BASE.

February 1st, 1892	$19\,L + 10\,175.3$ mm.
February 4th, 1892	10 158.9 "
February 5th, 1892	10 187.6 "

The mean of the three determinations of the tape-length at Delta is 100.61300 m., and at Lum Point 100.61310 m.

To compare these measurements with those on St. Albans base, the discrepancies on Delta base should be increased $\frac{38}{27}$. The discrepancy between the first measurement of Lum Point base and either of the others must be increased $\frac{38}{24}$, and between the two last by $\frac{38}{29}$, the measurement having been extended beyond the base monument. This is on the principal that the error increases as the distance, and not as the square root of the distance, when the distance is small. That is, the law of probabilities only holds for a great number of possibilities, and the method of least squares is not properly applicable to a few observations.

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678.

(Vol. XXX.—December, 1893.)

TERRESTRIAL MAGNETISM IN NORTH AMERICA. —DISCUSSION ON PAPER No. 637.*

By HENRY GOLDMARK, R. S. WOODWARD and CHARLES A. SCHOTT.

HENRY GOLDMARK, M. Am. Soc. C. E.—Is the method devised by Gauss and Weber for measuring magnetic intensity still used?

Mr. R. S. WOODWARD.—It is still used, with some improvements.

A MEMBER.—Are there any local sources of disturbance in making measurements of magnetic force?

Mr. WOODWARD.—There are such sources. In general, however, it is arranged to avoid them. Some difficulty is nowadays found in establishing permanent observatories, because there is so much electricity generated for various purposes. A few years ago, it was found that an observatory at San Antonio, Tex., was affected by an electric plant some distance away. This plant produced currents along water pipes laid in the ground near the observatory, and the disturbing effect of those currents on the magnetic instruments was so great that the observatory had to be removed to a new site. Great pains are always taken to avoid such sources of disturbance.

* "Terrestrial Magnetism in North America." By Charles A. Schott, Assistant U. S. Coast and Geodetic Survey. *Transactions*, Vol. XXX, page 108.

A MEMBER.—In a case which has come to my notice where observations were made near a locomotive shop, the disturbance to the magnetic needle was very great.

A MEMBER.—How great a distance is it essential to remove an observatory from sources of disturbance?

Mr. WOODWARD.—No general answer can be given to this question. Each case must be considered by itself. In refined work, the magnetic observatory is always placed at a safe distance.

Mr. CHARLES A. SCHOTT.—Apart from the disturbing effect on magnetic observations of terrestrial magnetism by the trolley and underground electric wire roads, by the storage car lines, by the electric light and telephone wires and by iron or steel structures of all kinds, which influences can generally be avoided by selecting a proper place for making the observations, there are also physical sources affecting the regularity of distribution of the magnetism of the earth's crust.

For convenience sake we may distinguish two kinds of disturbances, *i. e.*, those which appear quite local, covering only a few square miles, and which may be due to a single protruding disturbing mass, generally of the same polarity as that of the hemisphere in which they appear, and secondly, the larger disturbance extending over hundreds of square miles, distributed generally in one or more ridges, and, of course, closely connected with the geological formation. The tracing out of isabnormal magnetic curves, defining and measuring the disturbed localities, still remains to be done.

The investigation of the secular changes of magnetism has become more difficult on account of the impracticability, in most places, of revisiting the old stations.

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TREATMENT OF METALS FOR STRUCTURAL PURPOSES.—DISCUSSION ON PAPER No. 640.*

By L. L. BUCK, A. E. HUNT and J. E. GREINER.

L. L. BUCK, M. Am. Soc. C. E.—Naturally this paper is devoted to the treatment of steel. The treatment as well as abuse of iron as a structural material has been so thoroughly discussed that it would seem there is very little more to be said about it.

Steel has so largely superseded iron and has come into use so rapidly that our knowledge of its proper treatment has hardly kept pace with its adoption; hence any paper written by a man who has had as extended experience in working it as Mr. Christie must be a valuable contribution to engineering literature.

A reference to the paper in question shows such expectation to be fully justified; it is worthy of careful study by engineers and should be fully discussed. There would not be sufficient time for each member to discuss all the points of the paper. I have therefore decided to confine my discussion to such points only as my own experience has enabled me to form some opinion upon.

We are told that steel is a crystalline metal, and that good iron is fibrous.

* "The Treatment of Metals for Structural Purposes." By James Christie, M. Am. Soc. C. E. *Transactions*, Vol. XXX, page 155.

As regards steel, generally, this is doubtless true, and whatever error arises from treating it as a crystal will be on the side of safety. But iron, I take it, is fibrous only from the fact that when the puddle ball is passed through the rolls the particles of pure iron are kept more or less separated from each other by impurities, and these pure particles are elongated into fibers overlapping one another and welding together at numerous points. If for any reason a crack is started in such a material, it may be confined to but a fine fiber; while if a crack is started in a perfectly crystalline bar of steel, it would extend throughout the piece. Yet I have experimented with specimens of low carbon steel, by subjecting them to a slight nicking and bending test, and where the crack has started from such a nick, it has in many cases been arrested very soon and allowed of the specimen being closed together without further cracking. It was natural to suppose that in such a case the crack must have encountered a seam, beyond which was a surface of such extent as to allow of its stretching sufficiently to satisfy the bending. I have been told that this was an exploded theory, but exploded or not, the application of the microscope to such specimens showed such a surface, and I believe the crack will continue till it encounters such a seam. I have supposed that they must be caused by very fine bubbles which served to make the rolled material, in a measure, fibrous, as is done by the impurities in iron. If of appreciable size they would have a bad effect, where the bar was to be upset and forged, as in forming an eye-bar head or screw-end; but if very fine, they might arrest an incipient crack caused by shears or punch.

Mr. Christie states that low carbon steel is less liable to be cracked in punching or shearing than the higher sorts and that thin plates are less liable to it than thick ones. This is doubtless true. In short, anything which necessitates increased pressure in these operations, as, for instance, dull shears or punches, may cause cracks.

I am in favor of reaming all holes punched and all edges sheared in important steel members, and agree with Mr. Christie that such reaming should be done after the parts of a member have been assembled. Even with iron riveted work, I would have all holes reamed which did not agree closely enough to admit the rivet.

Most of us have seen the punched pieces of a member assembled when it did not appear possible to make the holes agree. But a gang

of men with drift pins and sledges would soon torture the parts into, apparently, happy family conformity. It would then go to the riveting machine and probably revenge itself upon the manufacturer by causing the machine and gang to be idle a quarter to a third of the time in drifting holes where the parts had been displaced, while other holes had been drifted. Had a gang of men been employed with hand reamers where the rivets would not enter, there would be no delay at the riveter and there could be no question as to the superiority of the work. Removing the sharp edges of the drilled or reamed holes by a slight countersink will not only benefit the rivet, but may prevent the starting of a crack in the plate as well.

As to driving field rivets, I hope the time will soon come when, by proper design of work and improvement of riveting machinery, most of such rivets can be machine-driven. When the stiffening trusses of the Niagara railway suspension bridge were erected, in 1880, I required all chord-splice rivets to be driven with 8-lb. to 10-lb. sledges, as the heavy sledges had an effect in upsetting the rivet very similar to that produced by pressure. The results have substantiated the theory. The Niagara chords were 80 000 lbs. steel, and have been subject to reversing stresses.

I only speak of this Niagara structure because it was some 15 years ago that the material was selected and it was a time when we did not know as much about steel as we do now, and, in fact, we knew, most of us, very little about it. It was something over 80 000 lbs. ultimate strength per square inch, and of course we could not get as good steel at that time as we can now. I had to reject 40% of all the plates that were tested. The steel was used in the chords of the bridge. They have been subjected to enormous stresses. In one case where a plate cracked and another was put in, I could not get a steel plate; and so had to put on an iron plate in place of it; the steel one was $\frac{1}{2}$ in. thick, the iron plate I made $\frac{1}{16}$ in. thicker. The first train that went over it pulled the plate in two. The other had been subjected to the very heaviest stresses for 14 years.

A. E. HUNT, M. Am. Soc. C. E.—Quoting from Mr. Christie's paper: "It is not intended here to discuss the quality of steel as determined by the component elements, a subject which has received ample attention at the hands of competent investigators. Suffice it to say that it is generally recognized that phosphorus and sulphur exercise an influence entirely evil, especially the former in its effects on material

when in service. If the manufacturer could banish them entirely, he would do so."

I would take exception to these statements as of broad, general and universal application, so far as my judgment goes. This is undoubtedly true regarding tool and other high grades of crucible steel, where there is a high percentage of carbon present, but I do not think it is true with reference to structural steel that has a carbon content ordinarily of less than 0.2 per cent.

Pure iron is a weak metal. I am not sure that it is as strong as the other metal in which I am interested—aluminum; that is, a tensile strength of not over 30 000 lbs. per square inch. It is only when a small proportion of other elements is added to it that the strength of wrought iron or steel is given to pure iron. When the percentage of carbon runs down very low and there is not some marked amount of phosphorus present, the steel produced is very low in tensile strength—below that of good wrought iron; that is, below 50 000 lbs. tensile strength per square inch, a material which is so soft that the unit strains ordinarily applied upon structural steel cannot be safely applied to it.

To counteract this weakness of very low phosphorus, manufacturers of basic open-hearth steel who have made their metal with less than 0.01% phosphorus have been obliged to add a considerably larger proportion of carbon, in order to obtain the tensile strength ordinarily required in structural material.

To get a steel of 60 000 lbs. tensile strength with the phosphorus below 0.015%, manufacturers of basic open-hearth steel in this country have found it necessary to run the carbon up to 0.3 per cent. Such steel is much more liable to take a temper by being cold-rolled or suddenly plunged into water when heated red hot. It is, according to my experience, a much more "tender" metal, in the way of being susceptible to changes, due to varying conditions to which it may be subjected, than steel which is lower in carbon and higher in phosphorus.

In the basic process in their efforts to reduce the phosphorus to as low a content as possible, carbon has often been run very low indeed in the melting furnace, and the steel has become liable to take up occluded gases and to be weak and rotten. I do not think, under ordinary conditions, that the general practice which has been widely

quoted, that phosphorus exercises an influence "entirely evil" in its presence in steel, and the manufacturer would banish it entirely if possible, is correct, or that the carrying out of this idea is good practice.

Undoubtedly the native ores that have produced stock for the manufacture of steel that was low in phosphorus have been of the best quality. I especially refer here to the materials producing the excellent results in Norway and Swedish irons. In a general way, also, the lower in phosphorus that structural steel can be obtained by the acid process, the better, for we have not yet found in this country ways of producing such metal with less than 0.02 or 0.03% phosphorus, except in very rare instances.

While I would advise boiler plate and steel of similar specifications to call for a maximum of, say, 0.03 or 0.04% content of phosphorus, I think that when we have gone to this limit for structural steel the specification will be as rigid in this matter as is wise; and, on the manufacturer's side, when he has produced a steel with phosphorus as low as 0.03%, he has gone as far as he need in purifying his metal in his endeavors to get a good structural material.

There are other causes for the production of poor steel beyond the content of phosphorus which can be better looked after than endeavoring to run the phosphorus lower than 0.03 or 0.04 per cent.

J. E. Greiner, M. Am. Soc. C. E.—The author states that public confidence is now fairly established in the trustworthiness of structural steel; that this confidence has been brought about by experience. He could have added that, while the reliability of steel of certain grades and processes has gained the confidence of the engineers who are called upon to use it, and the mechanics who manipulate and fabricate it into structures, the old-time respect for wrought iron has just as surely lost its hold and is gradually being crowded out.

It must be admitted that when steel was first introduced in the construction of bridges, our knowledge was limited and the metal was continually under suspicion, inspectors and chemists subjected it to every conceivable kind of treatment to satisfy themselves that when fabricated into a bridge of some 300 or more feet clear span, it would not fly into fragments like so much glass, upon the passage of the first locomotive.

The general idea of steel was a hard elastic metal, such as is used in

cutlery tools and wagon springs, liable to snap without warning especially in cold or frosty weather. One of the most prominent railroads in this country will not use steel in its bridges at the present time, in spite of the experience in its use and knowledge of its quality possessed by most bridge engineers. They still adhere to the wrought iron of the past and claim that steel is brittle, being liable to fly into fragments at the first shock, that it is liable to abuse in the shop, that it cannot be welded, that there is always a fear of small cracks having been started and not discovered, which sooner or later will cause a disaster, and, finally, that our knowledge will not justify its use—the same old objections which were advanced at its first introduction. This same company still uses iron eye-bars, relics of the past which are now made by but a few of the many firms engaged in bridge building, and which, although having from 50 to 75% excess of metal in the head, frequently break, not in the body of the bar as steel bars break, but through the head.

There was a time when wrought iron could be obtained, free from scrap, having an ultimate strength of from 50 000 to 52 000 lbs. with a correspondingly good elastic limit and elongation and a beautiful fiber. I have personally tested and inspected tons of this material and seen it fabricated in bridge structures. I have seen channel bars of the material made into posts with pinholes drilled near the ends, split open from the edge of the hole to end of web upon being roughly handled in the shop. I have seen I beam stringers made of this material after being in service a few years, suddenly split in their webs from the ends to a distance of 12 to 24 ins., flange angles of girders split along the roots by being struck a blow, any number of lattice bars and tie plates split by being punched too near the edges. All this was at a time when the mills agreed to live up to specification requirements and before the bridge builders got together and drew up specifications for qua ty of wrought iron, the result of which specifications has been to reduce the grade of material. Some railroad engineers being satisfied with the poorer grade, the mills will not at the present time undertake to make wrought iron such as specified by the Baltimore and Ohio specifications of 1885 except at a premium. Iron obtained now with an ultimate of 52 000 lbs. has very probably been doctored with steel scrap.

If, then, iron double rolled directly from the muck bars will so

easily split and crack, the poorer grade, such as now manufactured, has little to commend itself to the engineer, and why it is that some engineers will continue to give it preference over mild open-hearth steel can be attributed to a conservatism not well founded, as is clearly demonstrated by the experiment of Mr. Christie and many others.

The men who actually handle, punch, drill, shear and rivet up bridge members are the ones who favor a soft or medium steel to wrought iron. They have found that it can be bent cold into almost any shape without signs of fracture; that it can be used for lattice bars and tie plates where wrought iron would split out; that the former belief that it would fly into a thousand pieces if struck a severe blow was without foundation in fact; that when a girder dropped, the flange angles did not split along the rivets, as is the case so often with wrought iron; that eye-bar heads can be made to develop the full strength of the bars; that their work looked neater and cleaner when of steel. Those who know the least are the loudest in its condemnation.

Of course the foregoing remarks apply to steel made by the open-hearth process, either acid or basic, it being beyond question the best for structural purposes, because, as the author states, "the character of the product can be so readily controlled and predetermined."

Uniformity in quality is what is required, and the engineer naturally favors the process which will bring about these results, and although the managers of Bessemer plants will not readily acknowledge that their metal is not uniform from an engineer's standpoint, facts are arrayed against them which will require a long time and repeated demonstrations on their part to overcome.

The mills strive to produce a cheap product; they frequently produce mere jokes, having sacrificed quality and everything else to cheapness. Numerous instances are seen in the extremely poor quality of the Bessemer rails of heavy section now being made; rails which although weighing from 17 to 20 lbs. per yard more than those used five or six years ago, wear out and break, while the older rails are still doing good service. Several instances are on record where both Bessemer and open-hearth steels were used in the same girder which, upon being dropped on its flange, cracked the Bessemer angles clear across, while the open-hearth plates, which received the full impulse, merely

bent and were not otherwise injured. Another instance which recently came under my notice was the cracking of several basic Bessemer plates after having been punched and carelessly thrown to the ground. I have never seen nor heard of open-hearth steel acting in this manner, and am specifying it to the exclusion of other processes and wrought iron, in all railroad bridges now being built for the Baltimore and Ohio Railroad. Mr. G. B. Hazlehurst, M. Am. Soc. C. E., engineer in charge of bridge construction for the Baltimore and Ohio Southwestern Railroad, has also recently adopted the open-hearth steel in all bridgework. The specifications are as follows:

QUALITY OF STEEL.

General Character.—All steel must be uniform in quality and made by the open-hearth process. The finished bars shall be free from injurious seams, flaws or cracks and have a workman-like finish.

Phosphorus Limit.—The phosphorus in all melts must not exceed 0.08%, and certified analyses of all melts shall be furnished free of cost.

Melt Number.—All finished material must be plainly and distinctly marked with correct melt numbers.

Test Pieces.—Test pieces shall have a uniform sectional area of at least ½ sq. in. for a distance of 10 ins. Elongation shall be measured in a space of 8 ins.

Soft Steel.—When tested in specimens as above, soft steel shall give the following results:

Ultimate strength per square inch...	52 000 to 60 000 lbs.
Elastic limit.....	32 000 lbs.
Elongation in 8 ins.....	25%

Specimens must bend cold to 180° and close down upon themselves without sign of fracture. In tension tests, the fracture must be entirely silky. Holes punched 1½ ins. from edge of plate shall be capable of being enlarged 100% by drifting, without any sign of fracture.

Soft steel may be used under the same conditions as wrought iron, except that it must not be welded and that all bends be made cold or else the whole piece be annealed. The permissible strain per square inch may be taken 10% in excess of that given for wrought iron.

Medium Steel.—When tested in specimens, medium steel shall give the following results:

Ultimate strength per square inch...	60 000 to 68 000 lbs.
Elastic limit.....	35 000 lbs.
Elongation in 8 ins.....	20%

Specimens must bend cold to 180° around a curve whose diameter is equal to the thickness of piece tested, without sign of fracture. In tension tests, the fracture must be at least 80% silky. Holes punched 1½ ins. from edge of plate, shall be capable of being enlarged 66⅔% without sign of fracture.

Medium steel shall be used for pins and for eye-bars whose heads are to be formed by upsetting. It shall not be welded. All holes must be drilled. Bars must be carefully and properly annealed, permissible strain in such cases to be 12 000 lbs. per square inch.

Tests of Finished Bars.—Not less than 3% of the number of finished bars will be tested to destruction, and under this test they must develop the following :

Ultimate not less than ..... 58 000 lbs.
Elastic limit..... 30 000 "
Elongation, 12½% of total length, center to center.

Steel Rivets.—In all cases where steel members are connected by rivets, the rivets must be of the best quality of mild steel.

It will be noticed in the above specifications that medium steel is specified for eye-bars and pins only, and that bars are to be annealed; and that soft steel is used for all other members and worked under the same condition as wrought iron, excepting that no welding will be allowed. No restrictions are placed upon the thickness of the metal which is to be punched, for the following reasons :

First.—The designs are made under personal supervision, and an effort is made to limit the thickness to ⅝ or ¾ in. at the most.

Second.—Since it has been the accepted good practice to punch iron of this thickness and since mild steel is injured to no greater extent than iron and probably to a less extent, there is no more reason for limiting thickness in soft steel than in iron.

Some engineers specify that steel from ½ to $\frac{9}{16}$ in. must be reamed or drilled, and, when less than this, it can be punched. It is difficult to keep all members within the above limits, and this means that most of the holes are to be reamed, since it is not practicable to separate the material according to thickness, one lot to be punched with a certain die, the other with a different die, and then reamed to the same diameter as the holes in the first lot. When reaming is done, it is done after the pieces are assembled, and holes through any thickness of metal will be reamed. While reaming will be of great benefit, it entails an additional expense, and the cost will eat up the saving in metal due to

the increased permissible strains, as compared with iron, as usually adopted; moreover, reaming in soft steel is more expensive than in either iron or medium steel, on account of the metal clogging the reamer.

The above specifications were written to meet the immediate demands, and may be modified before being inserted in the printed specifications of the Baltimore and Ohio Railroad, now under course of preparation. For instance, I believe in limiting phosphorus to .05% in basic and .08% in acid open hearth, believing that this will place both processes on an equal footing, and will give very good results. Phosphorus could be eliminated entirely, if the manufacturer so desired, but, of course, at an increase in cost.

Outside of the above, I do not think it necessary to make chemical requirements in specifications, believing that, when the physical tests are satisfactory, the chemical composition should rest with the manufacturer.

As stated by the author, the best results combined with the least expenditure can be obtained by punching all holes when vital strains are not transferred by the rivets, and by reaming all holes in important joints and connections, such as stringers to floor beams, floor beams to posts, connection of web members of riveted lattice girders with the chords and tension splices. This practice is followed in some of the best shops, although with the idea of making well-fitting field connections rather than with the intention of removing injured metal.

The numerous tests made by Mr. Christie are valuable, and present facts in a form very acceptable to the engineering profession. Many such tests have been made by inspectors and others, and all convey the same general characteristics. Structures as built during the last 8 or 10 years have generally been well designed and without failures from an engineering standpoint, and holes have been mostly punched, reaming being used merely to obtain better matching. Experience has demonstrated that working strains as adopted in this country for this class of work are amply low; in fact, structures built 10 years ago are now, in many cases, strained from 20 to 30% in excess of the specified permissible strains and are just as perfect under these increased loads as they were when first built. I should not consider a well-designed Pratt truss or plate girder as a cause for uneasiness even when

the calculated strains would run up to 50% in excess of the present practice.

If, then, our structures be made of a much superior metal and this metal be carefully manipulated, as suggested by the author, a very important question arises, although not strictly pertinent to the subject under discussion, viz., "how high can we safely take our strains?" I believe the weights of engines and trains have about reached their limit, the heaviest engines not doing the work expected. If this is the case, we could take a load, say, of 120-ton to 125-ton engine, followed by 4 000 lbs. as a standard, and run our strains up to 30% in excess of present practice and have a structure which would do its work. I would not be the first to take such a step, and others no doubt feel the same way, and it is probable that we will continue to waste tons of material until in the future we find our bridges built for 80-ton engines still doing the same service as those built for 125-ton engines, even after most of us had predicted their failure by being shaken to pieces.

The life of railroad bridges has been heretofore about 20 years, not because the bridges wore out under the traffic for which they were designed, but because the traffic has, during that period, increased to such an extent that the old bridges, mostly of inferior designs, were no longer to be trusted with the excessive loads. If, then, as stated before, we could positively fix a limit to the weight of engines and cars, there would no longer be occasion to adhere to the so-called factor of safety of 5, one-fifth of which factor goes toward providing for a future increased loading.

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680.

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A PROPOSED METHOD OF TESTING STRUCTURAL STEEL.—DISCUSSION ON PAPER No. 641.*

By GEORGE S. MORISON, L. L. BUCK, T. S. WHITE, JAMES CHRISTIE, A. C. CUNNINGHAM, JOHN PURSER GRIFFITH and ALFRED E. HUNT.

GEORGE S. MORISON, M. Am. Soc. C. E.—There is one point in Captain Hunt's paper which has interested me deeply, though it is perhaps one of the lesser points. I will say something about it to start the discussion.

On page 187 he says that it is "perfectly practicable to equip the punches used at bridge and boiler shops in actual practice with some device for measuring the force or work done in punching; and by the aid of graphical devices a record can be kept of the characteristics of every piece of metal punched that goes into any structure." By following this we should have a perfect method of investigating the material in riveted members. Then, if we drew a specification which required the use of this registering apparatus and provided that the punches should always register within certain limits, every plate could be inspected and accepted as it was being punched. This would, I

* "A Proposed Method of Testing Structural Steel." By Alfred E. Hunt, M. Am. Soc. C. E. *Transactions*, Vol. XXX, page 181.

think, be an ideal method of testing, perhaps a little too near an ideal; but we may safely say that if this could always be done, no other inspection would be required. If we have a member which is perfect at every punched hole, I do not think it makes very much difference, of course within reasonable limits, what the metal is between the holes; furthermore if it is perfect at the holes it cannot be very bad between.

There are two or three objections, however, to the use of this method of testing. The first is that the testing machine has yet to be devised; it can be devised, but it is a new machine. The second is that I think in the best class of steel work it is better not to punch at all. We should fit our pieces together by planed edges in immediate contact, without any of the clearances which are now allowed for irregular rolling. When the pieces are fitted together in this way the holes should be drilled in the solid metal through the several pieces, in the actual positions which they will occupy in the finished structure. This is the only way to get first-class work, and it is the only way to get work free from initial strains.

Subject to these provisions it seems to me that Captain Hunt's paper is worthy of the most careful consideration; the method can undoubtedly be applied to all riveted members, but how are you going to apply it to either eye-bars or pins? The answer seems the simple one, that you cannot apply it at all. I know of no method of testing eye-bars which will give perfectly satisfactory results except that of taking every precaution to obtain uniform steel and then testing a number of the full-sized bars. As regards pins, there is a method of testing which I believe to be as good and useful as Captain Hunt's method of testing riveted plates would be. As I said before, I have advocated for some time drilling a hole through the center of the pin. In some pins made in one of the eastern shops the manufacturer voluntarily and without request bored the pins in such a way that a continuous round core was taken from the center of each pin. A core taken from the center of a pin is pretty sure to be the worst metal in the whole pin. If you will take a core from every pin and test it, both by bending and tensile strain, you will have a perfect set of tests for pins.

L. L. Buck, M. Am. Soc. C. E.—It has long been my opinion that a good place for an inspector of structural material is in the shop where the material undergoes the various operations of being made up into

the members of the structure for which it is intended. Much information can be gained by examining the chips removed by drill, lathe and planer, as well as by noting the action of the punch.

There is doubtless a relation existing between the resistance of the material in the testing machine and that presented to punching and shearing. If I understand Mr. Hunt's paper, he proposes to establish such relation, not for the purpose of dispensing with the testing machine, but to enable the inspector to obtain a more through acquaintance with the quality of the material, or, as it were, to make his method auxiliary to the testing machine.

That this may be done with valuable results by the use of the punch there is little, if any, doubt; but it appears to me that the method by shearing would present so many conditions dependent upon the form of specimen and its relation to the form and size of the cutting edges of the shears that it would be almost impossible to establish a relation between the tensile strength and the shearing resistance by that means.

The fewer the conditions to be noted in any method of testing, providing they are carefully selected and authentic, the better. Even with the punch there would be a variation with every change in size of punch, thickness of plate, proportion of size of punch to that of die and the sharpness of punch and die. The last two could be eliminated by specifying that the punch should have a given clearance in the die and that both should be kept sharp.

The shearing test would be useful for establishing the relation between shearing and tensile resistances, provided that the specimens are cylindrical and fit the dies with the same clearance that a pin usually fits in the hole for which it is intended.

It is evident from the results of Mr. Hunt's shearing tests, that the double shear would give more accurate results than single, as it comes more nearly to eliminating the frictional resistance than the case of single shear.

T. S. WHITE, M. Am. Soc. C. E.—One question I would like to ask Captain Hunt, in this method which Mr. Morison aptly styles an ideal method of testing if it could be applied in shop practice, whether the time required in punching is an essential? Captain Hunt, in one place, speaks of the time required being from 30 to 60 seconds for each test.

JAMES CHRISTIE, M. Am. Soc. C. E.—The method of testing structural steel proposed by Mr. Hunt offers a convenient and ready means for testing material in quantity, without submitting to the expense and delay of preparing specimens as now practiced for tension tests. If the upper shank of the punching tool was formed into a tapered drift, and a segmental die used which would open laterally when penetrated by the drift, the operator could not only measure the resistance to or work done by punching, but also that due to the distension of the specimen by the drift.

This is a test of great value for ascertaining the quality of iron or steel. It is a fact well known to inspectors, that sometimes steel will be found that does not properly endure the torture of the punch and drift, or bending test after punching, and yet yields satisfactory results when pulled in the testing machine in the ordinary manner. Nor is the chemist always able to disclose the secret of a particular weakness, which leads some to declare that no steel should be punched or sheared. It is quite probable that if specimens were sheared to a definite dimension, and offered a definite resistance to punching and drifting, and the punched holes distended a definite amount before cracking, we would have as useful a criterion as could be devised for judging the quality of structural steel.

A. C. CUNNINGHAM, Assoc. M. Am. Soc. C. E.—In a discussion upon steel rails before the American Institute of Mining Engineers in February, 1881, William Sellers, Esq., of Philadelphia, proposed the use of a registering punch to be used on the cross end of rails, as one of the methods for determining their quality. Mr. Sellers calls attention to the difficulty of applying a registering apparatus to regular punches, and concludes that, if used, a special machine should be adopted.

In the same discussion Professor Egleston, of New York, states as follows:

"Mr. Sandberg in his paper mentions the idea of using a registering dynamometer attached to the punching machines, and of determining the quality of the metal by the resistance which is shown. I think the first idea of this kind was published by Professor Langley, of Pittsburgh. * * *"

We thus see that the idea of determining the quality of steel by its resistance to punching has been considered before, but it does not seem to have met with much favor, as it has not come into general use.

The present methods of testing, which Mr. Hunt proposes to

abandon for a method of punching, shearing or drifting, have been used for many years, and are the development and result of observation and study on the part of those who manufacture and work in steel. Each test has its specific purpose and tends to develop certain qualities of the steel.

The tension test grades the metal, and the appearance of its fracture is a valuable guide to its properties, the combined results giving valuable indications of lack of work, cold rolling, overheating and burning.

Hot, cold and quenched bending tests give reliable indications of the presence of excessive amounts of the various constituents of the steel, as carbon, phosphorus, sulphur, manganese, etc., which are not developed by the tension tests. Drifting tests are not commonly made, but are of value in developing the ductility of the steel. Drop tests are of decided value for material subject to impact, as car wheels, rails and axles.

Other physical tests not mentioned by Mr. Hunt, but often specified or used, are as follows:

Drawing down the steel a certain percentage of its thickness under the hammer, either hot or cold, and called hot and cold hammer tests. Special punching tests to demonstrate how near together, or how close to a sheared or rolled edge, holes may be punched. Opening and closing tests in which the different parts of a shape, as the legs of an angle, are closed together or opened out. Upsetting tests in which the steel is driven back on itself. Nicked bending tests for the comparison of different steels, or the homogeneity of the same steel.

The use for which a steel is intended, or the treatment it is to receive, will develop suitable tests to be employed.

The chemical analysis of the steel, the most important of all, will in itself indicate to the practical observer the ultimate strength of the metal, and whether it is liable to hot or cold shortness, sensitive to impact or otherwise likely to prove dangerous under certain conditions.

The use of all the above-enumerated tests is not necessary for determining the value of a steel for structural purposes, and it is rarely the case that they are all applied. With the analysis of the steel, a tension test, a cold and quenched bending test, no steel need be accepted for a structure that is not entirely suitable; and if these tests are properly selected, one of each is sufficient for each cast of steel.

By cutting the ordinary tension test from 6 to 8 ins. longer than usual, the ends of the broken pieces can be used for making the bends, and the actual number of machined pieces required for three tests is thus reduced to one.

These methods of testing steel Mr. Hunt proposes to abandon for the following reasons:

First.—On account of the time required and expense occasioned, the tensile, chemical and drop tests are not sufficiently numerous to discover and check a lack of homogeneity in the metal.

In this connection it may be said that the time required to prepare an ordinary tension test will not exceed two hours from the time the metal is cold enough to cut; the number that can be actually prepared depending upon the facilities for so doing. In many mills 100 tests can be averaged daily. In one of the mills in this country the cost of preparing tests has been carefully computed and found to be about 22 cents per test.

The analysis of some of the elements of the steel can be determined before the metal is cast. The analysis of all the elements can be determined before the steel is ready for rolling. Drop tests can be made on the cross-ends of the material and require no preparation whatever. Any delays on the preparations of tests or analyses may be traced to lack of proper facilities for making them.

Second.—Variation in results of tests owing to location from which they are taken, and variations due to speed of testing, amount of impact, application of strains, and by pulling specimens out of line.

To these objections it may be said that the variations of results due to location of test piece will apply equally as well to a punching test as to a tension test. The amount of impact is settled by the specification for drop tests, and the speed of testing and application of strains cannot make a poor steel give good results. Pulling a specimen out of line is against the development of best results, and cannot be used to pass questionable steel. Location of test piece, speed of testing, etc., are all within the control of specifications.

Third.—The narrowing of the allowable limits of specifications by engineers, and the strict interpretation of the same by inspectors.

In this connection it may be said that the bridge builder's standard specification, made by the contractors themselves, set the allowable variations for the ultimate strength of steel at 8 000 lbs., and it is the

exception to find a specification in which the limits are narrower than this; where they are narrower, it is because the engineer wishes a still more uniform metal, or has been led to believe from his test reports that a more uniform metal can readily be made.

The specification of the city of Chicago allows a variation of 13 000 lbs. in finished material, and the specification of the U. S. Navy Department for the structural material of the new ships calls for a minimum ultimate of 60 000 lbs. and a minimum elongation of 25% in 8 ins., with no maximum limit of ultimate and no requirements of elastic limit or reduction of area.

Certainly, the narrowing of some specifications seems to be more than offset by the widening of others. No contractor is obliged to make material under a specification that he considers too narrow, and, if in doing so he has more or less steel rejected, he should find the fault in himself, and not in the engineer who made the specification, or the inspector who enforced it. Inspectors do not contract the requirements for steel inside the specifications; the manufacturer may be depended upon to enforce this, and engineers have doubtless found out that it is unwise to give inspectors unlimited powers to accept steel at their discretion.

How the substitution of a punching test for a tension test is going to remedy the narrowing of specifications, unless by temporarily befogging those who make specifications, is not readily apparent. The engineer who requires close limits for a tension test will require the same for a punching test, when he becomes familiar with it.

Fourth.—"Bending, drifting and similar tests of ductility do not give results, in numerical quantities, convenient for reference, comparison and record, or for exact stipulation of requirements in specifications."

Specifications give the angle to which tests must be bent, and the diameter of the circle around which they are to be bent. The angle and curve, whether greater or less than required by specification, to which tests conform, can be recorded numerically, or graphically, by placing on paper and drawing pencil marks around them. In the same manner, in the case of drift tests, the diameter of original hole and of drifted hole can be recorded numerically or graphically. In fact, any test involving a change in dimensions, or alteration of figure, can be recorded numerically.

The method for testing steel which Mr. Hunt proposes to substitute for the present method consists of registering the results of punching holes in the steel; the same cross-ends from which we take our present tests are to be utilized for the punching tests, and owing to the rapidity with which the tests can be made, and the slight amount of preparation necessary, a much greater number are to be made on each heat of steel.

The claims for this method do not hold in the case of car axles, heavy eye-bar flats, large rounds for bridge pins, rounds and squares of any dimensions, flanges of beams or channels, or any material of excessive thickness, or having surfaces not parallel. In such cases, fully as much, if not more, preliminary preparation will be required to prepare the tests than is now the case.

It is further proposed to equip the shop punches with a registering apparatus, whereby every hole punched in a piece of material may become a test.

Besides the preliminary cost of equipping the punches, it would seem that considerable delay in the work would be occasioned, even by recording the results on a part of the holes, and a more accurate observer than the man running the punch would be needed to make the observations.

The argument has been used that the bridge shops are subjected to annoying delays by the present method of testing, but by the proposed method it would seem that they might be subject to even greater delays and uncertainties.

In the case of drilled work, the shop observations become impossible.

The unavoidable variations in the conditions of punches and dies, and amount of clearance between the same, would alone seem to offer an insurmountable obstacle to this method of testing.

The punching tests made by Mr. Hunt were conducted under uniform conditions, but the results are so variable as to be rather discouraging in themselves, and, when the further variation of conditions is considered, it seems doubtful if this is a desirable method for testing steel.

With our present knowledge of steel, the need of detecting a lack of homogeneity is no longer necessary, for we may assume, without error, that no steel is homogeneous. What we need to determine is

that none of the steel that goes into our structures is outside the limits of safety.

In a paper by Mr. Pourcel, before another branch of this Congress, the subject of segregation is very thoroughly discussed. It has been shown that, no matter how thoroughly "mixed" or homogeneous a steel may be while molten, that, as soon as it is cast and begins to solidify, its constituents begin to separate out or "segregate" towards the still molten part of the metal. This tendency to segregate is decidedly marked for carbon, phosphorus and sulphur, and less marked for manganese. In consequence of this law of segregation, it is found that the elements of the steel tend to accumulate towards the axis and top of an ingot as long as any of the steel is molten, and will be in excess at the top near or on the axial line.

If the tests representing the steel are taken from the most highly segregated portions, the worst condition is at once known, and it may be assumed that the balance of the steel is better than that represented by the test. Thus the true condition of a steel may be shown to better advantage by the judicious selection of a few tests than by the indiscriminate selection of a large number.

Mr. JOHN PURSER GRIFFITH.*—Mr. President, the group of interesting papers on steel which the Civil Engineering Division of the Congress has had before it to-day proves to me that American engineers, like their European brethren, are rapidly appreciating the value of steel for structural purposes. In England, if the difficulties which lie in the way of welding steel could be overcome, there can be but little doubt that the manufacture of wrought iron would cease for commercial purposes. I should very much like to hear the opinions of some of the distinguished steel manufacturers of this country as to the practicability of welding steel with any degree of certainty. Cases occur to me in which steel bars have appeared to be perfectly welded, but, on being tested, it was proved that the surfaces in contact were only folded together or interlaced, and not welded. The uncertainty of steel welding is undoubtedly a drawback to its use for structural purposes, and I trust that the day is not far distant when this difficulty may be overcome. Mr. Hunt's suggestion to test steel by punching and measuring automatically the work done has interested me much. He no doubt is aware that the punching and drifting tests

* Of Dublin, Ireland.

are in use in England; but, as far as I know, no proposal has been made to register the work done in punching.

More than thirty years ago the late Mr. Robert Mallet proposed the adoption of a test of the work done in breaking iron by tensile stress. It appeared to me such a rational test that I have often wondered why its value has not been more fully recognized by engineers. Perhaps the absence of good automatic registering appliances, such as those described by Mr. Hunt, may explain the apathy with which Mr. Mallet's proposals were received.

ALFRED E. HUNT.—Mr. Morison states that "this proposed method of testing would, perhaps, be an ideal one, so that no other inspection would be required." It is not my judgment that this form of testing will ever replace mill inspection. One serious objection is that when the material is condemned at the bridge shop, the delays occasioned by the replacement are of such a serious character as to cause the use of material which would otherwise be condemned and which ought not to be used for structural work. Again, the tracing of steel as separate melts at the mills where it is manufactured, and reasonable supervision over this system of selection of the steel by melts is, so far as my experience goes, a necessity, to insure the proper inspection of steel.

I would not suggest the method to do away with full-size eye-bar tests. I believe this to be a very important and necessary series of tests in the proper inspection of eye-bars for any important work; but the same method of testing steel applicable for eye-bars and pins can be readily used; that is, the force required or the work done in cutting a given indenture can be measured as a method of testing with the larger blocks of steel used in eye-bars and pins.

Mr. Morison says: "I know of no method of testing eye-bars which will give perfectly satisfactory results, except that of taking every precaution to obtain uniform steel and then testing a number of the full-sized bars." I most thoroughly agree with Mr. Morison's statement in this, but respectfully submit that this method of testing can be used as one of the "precautions to obtain uniform steel," and by the ease and rapidity with which the tests can be made, more of them can be made upon any given lot of steel, and, therefore, more assurance obtained as to the uniformity of the steel in its selection for the fabrication of the eye-bars in the first instance.

While I admit that we have so far obtained more uniform and regular results with punching than with cutting and shearing, at the same time the same principle can be made to apply very satisfactorily with shearing, and I would refer any one who wants to investigate this matter further to the very valuable and exhaustive series of papers by H. V. Loss, published in the *American Engineer and Railroad Journal* about a year ago, with reference to the investigation of shearing work.

Another point, brought out by Mr. Buck, that it would be well to have the size of the punch, the thickness of the plate, proportion of size of punch to that of the die, and the sharpness of punch and die specified, or at least to eliminate as many of these varying conditions as possible. The clearance of the die should certainly be specified in any given series of tests. I think a study of the results of the tables will show the work upon the relative thickness of plate to be quite closely approaching the formula up to at least $\frac{5}{8}$ in. thickness, and the relative sharpness of the die can be readily checked by having standard pieces which take a known force to punch, or a known amount of work to punch, and checking the apparatus in this way often.

Answering Mr. White's questions, I think the appendix referring to the question of time shows that, while the conditions of the testing should be relatively as nearly alike as possible, a considerable variance in the time of making the punching test does not have a very material influence upon the results.

The suggestion made by Mr. James Christie of having the "upper shank of the punching tool formed into a tapered drift, and a segmental die used which would open laterally when penetrated by the drift," seems to me to be a very excellent one, and the data gotten by obtaining the distension of the specimen in punching or drifting would be valuable.

Answering the points of Mr. Cunningham, I wish to again call attention to the fact that it is clearly stated in the paper, and I wish to reiterate, that there is no proposal by me to abandon the present methods of testing. My idea is that the method of testing suggested can be much more readily and cheaply employed, and that it could be used as an addition; and very likely after it had been used in conjunction with tensile testing for some time it would be found to take the place of very many tensile tests. I do not believe, however, that it will ever be advisable to use this proposed method to entirely supersede the present methods of testing.

I thoroughly agree with Mr. Cunningham in his statement that drifting tests are of value in developing the ductility of steel, but I cannot agree with him in his statement that "with the analysis of steel and a tension test, and a cold and quenched bending test, no steel need be accepted for a structure that is not entirely suitable; and if these tests are properly selected, one of each is sufficient for each cast of steel." Melts of open-hearth steel are now made with from 10 to 30 tons of metal in each case; and this limited number of tests suggested by Mr. Cunningham I have found in my experience does not always record poor results, and cause the rejection of steel which is faulty on account of being non-homogeneous. This non-homogeneity is due to many different causes, among them being:

First.—Poor melting and irregular steel in its first manufacture in the steel furnace or converter.

Second.—Segregation of the impurities in large ingots of the steel.

Third.—The burning of portions of the steel.

Fourth.—The lack of sufficient work upon a portion of the metal.

The series of tests which Mr. Cunningham has outlined can often be obtained, and entirely fail to discover lack of homogeneity due to any one of these causes in a portion of the metal; the parts of the melt from which the tests had been obtained being entirely satisfactory, while other portions of the metal might be dangerously weak.

It is for this reason especially that I consider this method of tests a valuable one, as it allows more tests to be made upon any given lot of metal, giving thereby a better idea of its quality than can be obtained by the tests which Mr. Cunningham has enumerated, all of which I grant are valuable tests, and which have been so recognized and have become standard.

The cost of test specimens which have been made I grant has been increased in some of the larger mills, and the cost of preparation has been decreased by special apparatus. At the same time "100 test specimens pulled in a day," in a large steel mill are often not enough to prove the quality of the steel. Especially has this been the case when the steel works are working poorly and irregularly, and producing non-homogeneous steel. By the method of testing which has been outlined in this paper, 100 tests can be made and recorded in an hour, with a very small proportion of the expense that now is called for by the standard methods suggested by Mr. Cunningham, and which in ten-

sile tests under very favorable conditions he estimates to be about 22 cents in the preparation of each specimen.

I grant the truth of Mr. Cunningham's observation that variance in results, due to the location of test specimen, will apply equally to the punching test as to the tensile test; but this does not do away with the force of the statement given above of the great advantage of more tests, but rather adds to the necessity of the larger number of tests being obtained as can readily be done by the suggested method of measuring the force or work done in punching.

As to the substitution of punching tests for tensile tests remedying the narrowing of specifications, I have hopes that it will, for I believe that many intelligent engineers, in making the narrow limits to their specifications, do so with the idea that the narrow limit is required in order to insure homogeneity of the metal, and that, should they be able to get a much larger number of tests of any given lot of steel by this proposed method of punching, they would be willing to allow, with the larger knowledge of the character of the metal which could be obtained, a wider variance in the requirements of their specifications.

The same statements that I have made answering Mr. Morison's discussion regarding this method of testing being applicable for eye-bars and bridge pins of course would apply to car axles and large rounds and squares and other large sections of steel. It will be perfectly practicable to measure the force applied in cutting a given indenture in these large sections and thereby obtain a measure of the quality of the steel according to this method, although I have frankly to admit that this will require a considerable amount of data to be obtained by further experiments. At the same time I believe that this method can be adopted for this class of work. Of course, the method is more applicable to the very much larger number of sections of steel which are used in ordinary structural work, namely, plates, angles and ordinary structural sections which have some of their surfaces parallel.

Mr. Cunningham states that in the case of drilled work especially observations would become impossible upon this method of testing. I would call his attention to the fact that the same practice, I believe, will apply with considerable success in measuring the force and even the work done by a drilling tool as with a punch; and, from some data which I have lately obtained on this method, I am confident that a very

successful method of measuring the force required to cut a given indenture with a drill can be readily obtained.

I do not agree with Mr. Cunningham's statement that "the unavoidable variations in the conditions of punches and dies, and amount of clearance between the same, would alone seem to offer an insurmountable obstacle to this method of testing." Some of the experiments outlined in this paper, as well as a large number of others, have shown that considerable variation can be allowed in the condition of the punches and dies without materially altering the results, and that it is perfectly possible to keep the tools used in this method of testing in such condition without any extraordinary care or considerable expense, so that these considerations are not serious obstacles. However, I grant that it would be necessary in this method of testing, as in any other, to keep the condition of the punches and dies and the amount of clearance between them reasonably accurate. This can readily be done, and I again call attention to the fact that there is an easy method of checking the conditions upon standard pieces of steel which have been tested under favorable conditions.

Mr. Cunningham certainly cannot have studied the various appendices to the paper and state that the "conditions under which these punching tests were made were uniform." Many variances were obtained, both as to the thickness of the metal and character of it in being good and bad steel, and with two different sizes of punches.

I do not agree with his statement that the "results of the tables are so variable as to be discouraging" in this; and my experience does not lead me to agree with the further statement made by Mr. Cunningham that "because a test specimen may be taken from where presumably the highest segregations occur in the steel ingots, therefore the worst conditions have been taken," and that it "can be fairly assumed that the balance of the steel is better than that represented by the test specimens." I have already shown that there are other causes of non-homogeneity beyond that of segregation, and my own experience has shown that it is by no means safe to claim that any test specimen can be selected beforehand which contains the maximum content of impurities due to segregation in the steel.

Another objection has been brought to my attention, that the compressibility of the punch, as compared with that of the material, may be an important factor in this method of testing, and that I have not

mentioned this in my paper. By careful measurements of the punches used, before, during and after the punching operation, the results have shown that with ordinary work, and where the punch is not required to push through material of a thickness over the diameter of the punch, the compressibility of the punch is practically *nil* and is not a factor which enters into the measurement of the force applied, and, in fact, is not even a considerable factor in the measurement of the work done in the punching operation.

While I have to again frankly admit that there is much more work to be done upon this method of testing in order to utilize it completely, still, with each added day's experience with this method of testing, I am more convinced of its practicability and utility in testing structural material.

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681.

(Vol. XXX.—December, 1893.)

THE USE OF MILD STEEL.—DISCUSSION ON PAPER No. 643.*

By G. H. THOMSON, D. J. WHITTEMORE, GEORGE S. MORISON, ROBERT MOORE, WILLIAM METCALF and C. WEYRICH.

G. H. THOMSON, M. Am. Soc. C. E.—In Mr. Weyrich's paper, Vol. XXX, page 234, he states: "It is therefore urgently desirable that the previously approved mild steel may still continue to be used for all constructions without any alteration whatever."

The mild steel of Germany may not be, and probably is not, identically the same as the mild steels of our country; but, in view of the large quantities of so-called mild steels now thrown out on the market, much of it of a very doubtful character, it seems to me that we are justified in exercising more than usual caution in its use. We should use harder steels rather than softer steels—not too hard, however.

The main point in the quality of steel is to get ingots free from gas—a difficult matter in basic steels, unless the ingots are "cropped" for perhaps 40% of their length.

* "The Use of Basic Mild Steel as Material for Construction in Germany." By C. Weyrich, Engineer of River and Harbor Board at Hamburg, Germany. *Transactions*, Vol. XXX, page 219.

I have in mind a number of railroad bridges which have failed, or are failing, or are beginning to show evidences of failures due to the use of too soft, rotten and gaseous basic steels.

Railroad managers cannot be too wary in the acceptance of this uncertain and not very well-known material; especially should such metal be kept away from the punch and shears.

D. J. WHITTEMORE, Past President Am. Soc. C. E.—We are given to understand by Mr. Gleim that it is the intention to use steel throughout for bridge construction in Germany. I wish to say that in conversation with two engineers of trunk lines in this country I learned that it was their intention to use mild steel in eye-bars only, and that the balance of their structures would be constructed of wrought iron.

There can be but little doubt that considerable so-called mild steel of poor quality has been manufactured and used in this country. But a short time since some girders of this so-called mild steel were constructed in Chicago which required two cars for transportation. By mistake the coupling-pin joining the cars was drawn at the time shipment was to be made, which permitted the dropping of one end of the girders to the track—a distance of 4 or 5 ft. The result of this accident was that the girders broke in two; and certainly this should not have occurred had they been built of good material. Similar failures undoubtedly have caused mild steel to be looked upon with disfavor. Proper inspection of the manufacture of the steel should be insisted upon, to overcome this prejudice.

Mr. THOMSON.—I had an experience several months ago with a plate girder 140 ft. long and some 10 ft. wide. The girder was being loaded on a train of cars at one side. When up about 10 ft. the tackle failed and let one end of the girder down. The splice in the bottom flange stretched, but there was no other injury to the girder.

GEO. S. MORISON, M. Am. Soc. C. E.—Speaking of injuries to bridges, I should like to mention one that occurred to a steel draw-bridge built under my direction. It was the bridge across the St. Johns River at Jacksonville, Fla. A schooner which was towed by a tug attempted to go through the draw without giving proper attention to steering. The tug in coming down the river followed a course which made a sharp angle with the axis of the bridge and, when opposite the draw, turned suddenly and went through the draw opening, expecting the schooner to follow the same course. The course of the schooner, however, was deter-

mined by the direction of the tow line. First the schooner struck one of the piers and knocked off a cathead, losing one anchor. It then rebounded, passed through the draw opening, struck the draw protection, knocked off the other cathead and lost the other anchor. It then struck one of the vertical posts of the draw with the bowsprit, the force of the blow being so great that the bowsprit was broken off where it entered the hull of the schooner, it being a solid pine stick 26 ins. square at the place of fracture. The force of the blow bent the post which was struck, bent the bottom chord, and was such as to send the draw home and close it. As the chord was bent up at the post it was down at the end, so that when the draw was closed it locked itself, and it was eight hours before it could be opened. All this was the result of a single blow. The only member that was so injured that it had to be replaced by a new member was the vertical post which received the blow, and this in my judgment was not so seriously injured as an iron member would have been in the same place. The draw was patched up, a temporary timber post was inserted and used for the remainder of the season, and in the following summer, when traffic was light, a new post was put in. The bridge was all of medium open-hearth steel, punched and reamed.

ROBERT MOORE, M. Am. Soc. C. E.—Referring to the examples that Mr. Whittemore has given, I may mention two in my own experience. In the construction of a line of elevated railway I was afraid to use steel for the anchor bolts. They were large anchor bolts, and in deference to the general opinion as to the danger of cutting threads in steel, I used iron. The only members of the whole structure, however, that failed, were two of those iron anchor bolts. If I had used steel I should have been sure that it was the fault of the metal.

On the other hand, a post in the same structure, made of mild steel, sustained the shock of a collision with loaded freight cars, without serious damage. The cars were entirely reversed in position and brought to a standstill, but the post was so little damaged that it continued to do service for over a year.

A MEMBER.—Were those screws with upset ends?

Mr. MOORE.—Yes, sir.

A MEMBER.—They had been upset and annealed?

Mr. MOORE.—They had been upset, and many of them had been annealed.

A MEMBER.—Did they break in the thread?

Mr. MOORE.—They broke in the thread, or close to the thread.

WM. METCALF, President Am. Soc. C. E.—Mr. Chairman, the only apology that I have to offer for taking up the time in this discussion is that my name has been mentioned once or twice to-day, and that I think I can point out some of the dangers to engineers in the use of steel, which will, perhaps, help them out of difficulties in regard to it.

You hear a great deal about mild steel and making steel mild by getting low tensile strength and great elongation; this is especially true in regard to boiler steel. I have only heard that kind of steel properly characterized once in this discussion, and that was by Mr. Hunt, when he said it was rotten. The matter with your mild steel, when it is too low in tensile and too great in elongation, is that it is simply rotten, by being melted, or blown, too low in carbon, because of the impossibility of removing afterwards the excess of oxygen and nitrogen that is thrown into it by that operation. After a number of years of careful study by Professor Langley, as well as in practice, we were convinced that the lowest blown steel and the lowest melted steel contained the most nitrogen and the most oxygen. We also found to our surprise, that the reason that we could sometimes put into the crucible the best material in the world and melt it into a rotten product was because we melted it too low in carbon; it would not take a bending test or a welding test. In the nice crucible work we were compelled to be cautious about melting too low. When we first found this, we kept getting it lower and lower and worse and worse, until we discovered what the trouble was. If engineers could get at this matter properly, could insure that no steel was ever melted in open hearth below 15 carbon and none blown in Bessemer below 15 carbon, and they need not be carbonized above 20 to 23, which is sufficient to remove all of the oxygen which can be removed; they might have a steel that some would call high steel, but it would be vastly better and safer than any steel of .04 to .06 carbon. If I knew it, and I were making boilers, for instance, no such steel as .04 to .06 carbon should ever go into a boiler of mine. We have numbers of boilers in our works where the carbon is up to 25 and 30. There is no danger of those boilers bursting. I have seen them bagged away down by bad firing and set up again without trouble. The secret of the failure of steel to weld is generally from too low carbon and being too high in

what we call gases. Steel really does not weld in any case, and it does not stick together properly if melted too low or blown too low. If engineers could get the idea out of their heads that the maximum safety is in the minimum strength, and would use a steel never melted or blown below 15 carbon, and which need not necessarily go above 25 carbon, I think all of these difficulties would disappear. In this exceptionally mild steel, so over mild or over blown, it is so full of gas that it is almost impossible to get a sound ingot.

Mr. Morison spoke yesterday of boring his pins on account of being piped. Sir Benjamin Baker spoke of members where the steel failed from the interior. It was not sound in the ingot; it could not be made sound. You may test it and not discover the defects, yet they are there. In hammering round pins there are liable to be holes in the center which are caused by hammering; by boring a hole through the middle of the pin you remove any possibility of there being a defect there, or, if it is there still, it can be seen and the pin can be rejected, and thus get a safer pin; because if there is a place in that pin, even at the center, where the integrity of the material is destroyed, the constant deflections will start a fracture at that defect, and it will grow until it goes through all of the material and causes a breakdown.

Mr. WHITTEMORE.—A mild steel?

Mr. METCALF.—Any steel, all steel. I have only taken the time to say what I have, because I think the dangers in the use of steel have been increased by the use of too mild steel. You cannot get too much sulphur in it, because it cannot be worked. With regard to melting in the open hearth, if you do not melt too low, a certain quantity of phosphorus will come out in the process any way, and excessively low melting is not necessary. The harm done in melting away down to take out all of the phosphorus, is shown when testing; the oxygen, nitrogen and hydrogen are elements of harm which cannot be removed to a safe degree when the steel is too soft blown or melted.

Mr. C. WEYRICH.—In regard to the mild steel treated of in my paper, I beg to repeat that it refers to the use for bridges and buildings, and not for engine or railway construction, such as rails, ties or rolling stock, for which purposes a somewhat harder material would be in place. There can be no question as to the milder material required for bridge building being more difficult to produce, particularly by the

Thomas process, special care being required to avoid red-shortness. This has led to the tests in Germany being made in two opposite directions, excluding too hard a material on one side, and preventing its being too soft or red-short on the other side, by specifying a lower as well as an upper limit of textile strength. For a steel tested in this manner there would be no more objection to shearing and punching than for wrought iron; and if the specifications nevertheless exclude these methods of working, the reasons are about the same as those excluding their use in wrought-iron structures of importance, a better quality and greater neatness of work being aimed at.

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682.

(Vol. XXX.—December, 1893.)

STABILITY OF QUAY WALLS.—DISCUSSION ON PAPER No. 646.*

By PETER VEDEL and C. O. GLEIM.

Mr. PETER VEDEL.—The importance of this question to all harbor engineers would excuse me for a few remarks. In its original shape this wall was of the combined type, partially a stone wall and partially a bulkhead. As such, it had to act on two quite different principles. The wall resists the pressure of the earth by its weight; the bulkhead, by the passive pressure of the earth in front of it. It does not call into action any other force; it makes the earth pressure, so to say, annihilate itself. I am well aware that this advantage is only, to a great extent, apparent, inasmuch as part of the errors in the assumptions as to the constants of the earth, instead of eliminating each other, rather, as entering into the active and passive pressures with different signs, will increase the uncertainty of the calculation. The top part of the wall is easily calculated by the usual formulas for determining the earth pressure on it. We know that, if its back side is given a certain batter, those formulas will give the same result as the rational theory of earth pressure based upon the differential equations, and we know,

* "Method Used to Secure the Stability of a Quay Wall at the Port of Altona, on the Elbe, in Germany, which had Shifted its Position after Completion." By Berthold Stahl, Stadtbaurath at Altona, Germany. *Transactions*, Vol. XXX, page 284.

too, that the pressure found will then be the actual one, whether the assumptions of one theory or the other be nearer the truth. But the bulkhead which forms the substructure of this wall is not so easily calculated unless it is decided to construct it as a usual bulkhead, to sustain the earth pressure independently of the weight of the stone wall. It seems very dangerous to count upon the joint action of those two different principles. The bulkhead may allow a certain small movement by its elasticity, just sufficient to crack the wall. The absence of land ties in the original type seems to indicate that the substructure has not been considered an independent bulkhead. In the altered wall I understand that the stone-wall principle has been abandoned altogether and the bulkhead principle adopted exclusively. True, the old front wall carries part of the weight of the cranes, but the new concrete wall which has been built behind the sheet piling takes up the pressure of the backing, and the sheet piling must, therefore, in connection with the piles, sustain the whole pressure by the passive earth pressure in front of the piles and on the wooden shields at the end of the stays.

I happen to have been in contact with a similar case, in the new harbor of La Plata, at Ensenada, in the Argentine Republic. The wall was 10 or 11 m. high, and the lower part was built of concrete deposited between two sheet pilings, which were supported by two rows of vertical piles driven into the solid clay. The top part of the wall was of masonry and fully strong enough; but, as a whole, the quay wall could not sustain the pressure of the loaded backing by its own weight, and it had to depend on the co-operation of the vertical piles. The result was that about 1 250 ft. gave way. To unload it by removing the earth and filling in with mattress work did not stop the motion. It was then tried to anchor the wall by chains to the piles, on which the superstructure of the sheds rested, but at an unusually low water the motion took greater dimensions. It was almost exclusively an overturning around the toe of the wall. The outer row of piles under the sheds followed the motion, and were nearly drawn away from under the superstructure. With other chains they were secured to the back row of piles under the sheds, but even then they began to move, and only the rise of the water prevented further destruction. In the reconstruction of this wall it was decided, instead of adopting, as in Altona, the bulkhead principle altogether, rather to do away with it; and a new,

substantial concrete wall was built in front of the old one, sufficiently strong to stand the earth pressure by its own weight, independently of the piles. It is a curious coincident that the cost of this work was about $500 per linear meter, or, considering the higher wages and transportation costs, the same as in Altona, by the reconstruction upon the opposite principle.

In the harbor of Copenhagen, Denmark, walls have been built upon the combined principle, as far as materials go, but not in the dimensioning of the construction. In renewing old bulkheads their over-water part is cut away; sheet piles and bearing piles are driven and connected with the land ties of the old bulkhead, and, where necessary, new and longer land ties are provided for; and on that substructure the top stone wall is built. In that way the under-water part of the bulkhead is the same or stronger than before, and can, independently of the weight of the wall, stand the pressure. To sum up, it seems advisable, therefore, in the dimensioning, to count only with one of the two principles acting at a time, even if other considerations make us choose to use such combined construction.

C. O. Gleim, Cor. M. Am. Soc. C. E.—In reference to the criticism on the original plan, I beg to say that the same design for the cross-section and foundation of quay walls has been employed in Hamburg, where such constructions have answered the purpose very well. I do not see how the substructure can be looked upon as a bulkhead acting on the principle of resistance by the passive pressure of the earth in front of it. I do not consider the lower part as anything but simply a pile substructure intended to take up the vertical and horizontal stresses brought upon the wall and the sheet-piling. The land ties that were afterwards constructed were not originally required to make up the stability of the quay wall; nor would they have sufficed afterwards unless they were fixed in the stratum of clay underneath. According to the author's representation this was a case of a landslide taking place along a certain sliding surface, as shown in Fig. 1 on the plate, and carrying away the quay wall together with its back-filling and the freight shed. The wall has now been anchored to the fixed subsoil. No anchorage constructed on the principle of an ordinary bulkhead anchorage, even with sufficient weight of the ground resisting the anchorage, would have answered the purpose if the anchors had been placed in the sand-filling over the sliding surface.

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683.

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UNDERGROUND SOURCES OF WATER SUPPLY.—DISCUSSION ON PAPER No. 647.*

By CHARLES B. BRUSH, L. L. TRIBUS, D. J. WHITTEMORE, D. W. MEAD and B. SALBACH.

CHARLES B. BRUSH, Vice-President Am. Soc. C. E.—I ask your attention to the paper by Mr. Salbach, of Germany, which has many points of interest; it is a discussion of one of the most important questions that comes before us, viz., the question of subterranean water supply. The author dwells at length on the fact that large subterranean supplies are always obtained in valleys. He says:

"The reason for the location in valleys of water works depending on a supply from wells is generally to be found in the situation of gravel and shingle deposits which, reaching down from the mountain ridges to the valleys and carrying off spring water, are exposed to a greater extent in the deep cuts formed by the river valleys than elsewhere. The greater part of these depressions was formed by movements upon the earth's surface a long time before the existence of rivers as they are now, and the deposits of gravel and shingle referred to are of much more ancient origin than the rivers themselves, which latter are generally excavated in more recent formations. Especially inter-

* "Experiences Had During the Last 20 Years with Water Works Having an Underground Source of Supply." By B. Salbach, Baurath at Dresden, Saxony, Germany. *Transactions*, Vol. XXX, page 293.

esting examples in this regard are the sources of supply of the water works in the valley of the Rhine, of Bonn, Cologne, Elberfeld, Düsseldorf, Mannheim, and also of the city of Dresden."

After discussing this point at considerable length, the writer goes on to show that the prejudice that exists against subterranean supplies is based on the theory that water thus obtained is merely water from an adjoining river.

He says :

"Examples of the yield of large quantities of spring water for many years will counteract the often-expressed prejudice that all such works yield nothing but filtered river water, especially as the votaries of this opinion generally deny the possibility of a natural filtration of river water. The direction of a current of spring water into wells must primarily be considered, in order to get a clear idea of how the wells are fed."

Then on page 314, he says :

"Some borings put down in the bed of the Elbe itself to a depth of 23 to 26 ft. showed that the ground-water in these bore holes would rise some 6 ins. above the level of the river. An examination of the samples of the water taken from the last-named bore holes showed a quality of water which, like the samples taken on the right bank, was softer than the Elbe water and of the same constituency as that from the bore holes first named."

It is the experience of every one who has examined this question of subterranean supply that there is a great distinction between water from a river, and water taken from adjoining subterranean sources not connected with the river. A very interesting illustration of that fact may be seen at the water works at Princeton, N. J. The water supply there is taken from the valley of Stony Creek. I drove a tube well about 35 ft. deep through the bed of this creek. For several years a stream of water flowed freely and probably still is flowing through this tube to an elevation about 3 ft. above the water in the creek. The water in the creek is polluted. This water that rises in the tube through the waters of Stony Creek is pure and clear and shows by analysis to be a different water from the water of the creek itself.

In Jamestown, N. Y., there is a remarkable subterranean supply, which is undoubtedly obtained from higher lakes at a considerable distance from the town. The water rises in tube wells near the town to a height of about 40 ft. above the surface of the ground. Lake Chau-

tauqua at Jamestown is lower than the elevation at which that water rises in these tube wells.

Long Island, N. Y., presents probably the greatest example that we have of a subterranean supply in the eastern part of the United States. Wells will flow at an elevation of several feet above the sea level. The inclination of the ground-water as it rises from the sea is about 9 ins. in 1 mile. Water can be obtained in large quantities almost anywhere on Long Island by boring for it. The total amount of water supplied to the city of Brooklyn is in the neighborhood of 68 000 000 galls. per day, of which amount 20 000 000 galls. are obtained from driven wells. All along the island and in the vicinity of these city wells there are other wells, which supply large quantities of water.

Perhaps the best illustration in the western part of this country of a subterranean supply, is the city of Memphis, where they are using about 10 000 000 galls. per day. The supply is obtained from a stratum of fine sand about 700 ft. thick commencing about 200 ft. below the surface. Above the sand there is a tight, impervious material; but when that material is tapped, the water rises to an elevation of about 25 ft. higher than the water in the Mississippi River at Memphis.

A similar and perhaps the same subterranean stratum that supplies Memphis has recently been tapped at Savannah, Ga.

This paper of Mr. Salbach is interesting, not only in the particular to which I have called your attention, but in the general discussion of the whole subject of subterranean water supply. There is one phase of the paper which will be interesting to American engineers, which reads:

"The experience of the year 1892 has shown that great caution should be exercised in determining upon the actual amount of consumption. The long-continued drought of that year caused an excessively large use of water and but few water works were in a position to meet the same. It was found that the maximum consumption in that year in Dresden was over 40 galls. per day per head and the water works had to restrict the amount supplied to the public fountains, so as to provide for the event that the consumption would increase still further."

In view of the fact that many cities of this country are using 200 galls. per head per day, and but few are using less than 100 galls., it is refreshing to learn that in some parts of the world they consider 40 galls. per day per head a maximum quantity.

There is one feature which I had hoped to see mentioned in this paper which has not been incorporated; the author has not shown us how he has obtained water from subterranean sources. He speaks of putting down wells, but does not say how he puts them down. He gives no idea of the mechanical appliances used to obtain water. The natural way where the water can be obtained within a depth of not exceeding, say, 50 ft. from the surface is to sink a large open well. But it has been found that a large open well will only yield a limited supply of water. The experience of Brooklyn is that an open well 50 ft. in diameter and sunk into about 20 ft. of water has an extreme yield of only about 1 000 000 galls. per day. This, of course, is not sufficient to meet a large consumption, and therefore other means of obtaining the water are necessary. The most common is to put down tube wells and to connect these tube wells with the suction main.

For some time the principle of the ordinary driven well was employed; that is the way it is done in Brooklyn. Two-inch or 3-inch wells with screened, perforated points were driven down into the water-bearing strata, and then suction was applied directly to these tubes.

Another method is to sink a perforated casing, put a tube inside and draw from this interior tube. That is the way more usually employed now in the collection of water; that is the way that it is done in Memphis and in many other portions of the country. It would be exceedingly interesting if we were informed of the methods employed in Europe in the different towns mentioned in this paper. The supplies that have been obtained in the instances recorded in the paper are usually comparatively small. Definite statements are not made in many cases as to the amount of water supplied. Some data are given, however. The city of Bernburg on the Saale has a supply of 1 000 000 galls. per day. The supply of Crefeld on the Rhine is stated as 7 500 000 galls. per day. The supply of Dresden, of which a very interesting description is given, has reached about 12 000 000 galls. per day. The number of inhabitants is about 300 000. This city recognized the fact that it is dangerously near its limit, and it is making arrangements for an extension of the supply up to 22 000 000 galls. per day. This is the largest supply that Mr. Salbach refers to as being in actual operation. It is stated, however, that arrangements are now being made for a supply from subterranean sources for Vienna, the minimum yield of which will be 50 000 000 galls. per day, and the

maximum 100 000 000 galls. That is so enormously in excess of any subterranean supply that has been obtained in this country or elsewhere that it would be interesting if we knew the method by which they propose to obtain so large a quantity, and what the result is likely to be, especially in the surrounding country, of continually pumping so large a supply of water from a subterranean source.

L. L. TRIBUS, Assoc. M. Am. Soc. C. E.—Mr. Brush has mentioned two interesting districts in the South for underground water supplies, viz., those around Memphis, Tenn., and Savannah, Ga. They are separated most completely, however, by the southern prolongation of the eastern ranges of mountains. The Savannah district being more of sand, clay and ocean deposits, while the Memphis district is on the edge of the great silt deposit forming Louisiana, Mississippi, southern Alabama and western Florida.

A few years ago I had occasion to examine various portions of this latter area for underground supplies of water, and was exceedingly interested in its study. Numerous driven wells have been sunk in various portions of the tract, with excellent success in some, fair in others, and complete failure in still other parts. The water-bearing strata were found at depths ranging from 50 to 1 000 ft.

In boring these wells but little is encountered except alternating layers of vari-colored clays, sand, silt, fine gravel, and occasionally a thin layer of hard pan—a few of the clay strata being quite thick, from 10 to 50 or more feet, of a dark blue color and a fine texture, almost free from grit.

In the western portion of the tract silt predominates, being the detritus carried down by the Mississippi River from the alluvial plains of the north and west, while the eastern portion is composed more of sand, coming from the nearer mountain ranges, and, owing to its shorter water carriage, is less ground up.

Western Florida seems to be an ideal locality for the driven well—largely of this sand and gravel deposit, with little silt or vegetable matter in its make up, and the mountains of northern Alabama and Tennessee to catch the rains and start the waters southward to the Gulf of Mexico. For an area of about 100 sq. miles in this western end of Florida, the water flows freely when these gravel strata are tapped at depths ranging from 50 to 300 ft., is of excellent soft quality and about 70° in temperature. I cannot say but that greater depths

would have given increased flow, but those mentioned gave sufficient satisfaction, with moderate expense in driving.

About 10 or 15 miles out from the Florida shore in the Gulf of Mexico, and for a stretch of about 100 miles or so, there have been frequently noted vast springs of fresh water boiling up, from a depth of from 100 to 300 or more feet. This fact, with that of a rise and fall of tide of about 12 or 15 ins., only once a day, should be noted.

Back about 1½ miles from the shore front in the city of Pensacola, were driven, some seven years ago, a series of 4-in. and 6-in. pipe wells to depths from 60 to 280 ft., at a point where the ground elevation was about 20 ft. above tide level. Water rises in these wells to within 3 or 4 ft. of the surface of the ground, or to 16 or 17 ft. above tide level, and they furnish with direct suction from 50 000 to 150 000 galls. per day each, yielding a total at that time (1886) of from 1 500 000 to 2 000 000 galls. per day.

These wells, though flowing at this height above tide, rise and fall from 6 to 10 ins. daily, apparently with the tide. This looks decidedly as if they have direct free communication with salt water and are merely tapping the underground rivers which supply the great Gulf springs miles away.

All along this portion of the Gulf Coast numerous fresh-water springs are found on the beach just above high water-mark.

The strata from which the Pensacola water is drawn are almost entirely a white gravel mixed with fine white sand and overlaid with beds of a very hard blue clay, but there are many small layers of various kinds of clay and colored sands encountered in the borings.

To the eastward of this "sand," as distinguished from the western "silt," basin, which by the way is very deficient of good potable underground waters, the character of soil changes and soon reaches the limestone, cavernous spurs of the mountains, which run out beneath the surface in the peninsula of Florida.

This locality, furnishing abundant supplies of water, often under considerable pressure, for instance, St. Augustine and Jacksonville, might be called the "artesian" as compared with the "driven well" district to the westward. But these waters are universally impregnated strongly with carbonates and sulphur, and are therefore unsatisfactory for domestic use.

Following the Atlantic Coast northward the sand deposits are again

reached, yielding good potable waters, as evidenced at Savannah, Charleston, etc., as before mentioned.

These items can scarcely be considered so much discussion of Mr. Salbach's paper as additional notes on the general topic of underground supplies, from the experience of another observer.

D. J. WHITTEMORE, Past President Am. Soc. C. E.—Mr. President, I regret very much that there has not been some paper upon the artesian features of our country. Allusion has been made to the southern portion of the country—I wish to call the attention of the members to the artesian features of Dakota. Take from Yankton, north, or the James River Valley throughout almost its entire length, and boring almost anywhere in that valley and close up to the coteaus on the other side, the valley is about 30 to 50 miles wide, an immense flow of water is struck; and so far as my own knowledge extends, the static pressure is about 50 lbs. per square inch. Those who know the features of the country, how subject it is to drought, can appreciate something of the value of an artesian supply. I trust that some member, at our next convention, will take up this matter of artesian supplies in this country and give a paper on the subject.

D. W. MEAD, Assoc. Am. Soc. C. E.—This paper by Mr. Salbach is of particular value to American water-works engineers on account of the wide interest which has lately been taken in subterranean supplies in this country.

In the United States, as in other countries, the most obvious sources, the surface waters, were the ones first utilized. With the increase of population these, in many instances, have become so polluted as to render them unfit for use, and many cities are therefore seeking new supplies. Where the pollution is not a present reality, but a near future possibility, the resulting dangers, as illustrated by the Plymouth, Pa., epidemic, bears such important relation to the public health as to render a change to a source free from possible danger greatly to be desired. In new work, where it is possible to secure a source beyond the possibility of pollution, or at least where the possibility of pollution is very remote, the selection of such a source is only a reasonable and necessary precaution for the preservation of the public health.

Subterranean supplies demand for their proper consideration and development a general and local geological knowledge; for only with

such knowledge can the possibility or probability of the existence of such supplies in any locality be determined.

They may in general be considered as derived from one of three sources—

First.—From the underlying stratified rock deposits.

Second.—From the drift sheet.

Third.—From the fluvial and lacustral deposits in river and lake valleys.

1st. The stratified rocks being, as a rule, laid down in ancient seas or lakes, their water-bearing strata are comparatively extensive, and the water exists, not usually in the form of underground streams, but more like extended underground lakes as extensive as the water-bearing deposit itself, and having a current usually in the direction of the dip of the strata. In some of the less porous strata, however, such as the archean rocks and the limestones, the contained water is held, not so much in the mass of the rock itself, as in cracks and fissures. The flow of water through these cracks and fissures sometimes results, especially in soluble limestone rocks, in the formation of caverns through which the waters undoubtedly flow as streams. This is not common, however, and the ordinary idea of underground streams is largely erroneous. The water in these strata is received from the rainfall and flow of streams at and over its outcrop, and flows thence toward the sea, frequently reaching the surface, naturally through fissures in the overlying rocks, as springs, or artificially through bore holes as artesian wells. The outward pressure and depth of these waters are often so great as to preclude the possibility of any pollution before reaching the outlet, and if properly cared for at the surface, they are organically the purest of all waters, although frequently highly mineralized. Such water-bearing strata are found in the upper Mississippi Valley, in the Potsdam and St. Peter sandstones, from which numerous private and public supplies are obtained, many wells being drilled into the latter, and a few into the former, in and about the city of Chicago at depths ranging from 700 to 2 700 ft. In the Dakotas and northern Nebraska, similar supplies are encountered in the Dakota sandstone at similar depths, while the cretaceous deposits furnish the source from which Memphis, Tenn., is supplied, and from which many wells along the Atlantic coast are derived. Other similar sources exist, some utilized, and some unutilized, in various parts of the United States.

2d. The drift sheet which extends over the northern third of the United States and over the greater part of British America, is a deposit so irregular in formation that a careful study of its origin and method of deposition is necessary for a thorough understanding of its possible value as a source of supply. This deposit is the result of ice and water action, and in many cases contains water-bearing sands and gravels, sometimes of vast extent. They are, however, commonly more local in character than in the case of the stratified rock deposits previously considered.

The contained waters, therefore, are in this case more of the character of underground streams, and vary largely in breadth and depth, following the sands and gravels of ancient glacial flood deposits. Often they occur in seemingly isolated streaks and veins in thin or narrow deposits of sand or gravel, surrounded by the glacial clays, in which cases adjacent wells may differ greatly in depth and entirely in the immediate source from which their waters are derived. The general direction of flow is, as a rule, in the direction of the glacial motion, which caused the deposits. Supplies from this source, especially when near the surface, require careful observation, to determine their source, character, amount and liability to local pollution. In many cases, however, the deeper waters from the drift are organically almost as pure as the waters of the lower stratified rocks, and often contain much less mineral matter. The drift formation varies from nothing to a maximum depth of perhaps 400 ft. From this source are derived most of the common wells in the northern States, and many of the municipal supplies.

3d. The stratified deposits in old lake and river valleys which have been filled to some extent above the bed of the ancient stream or lake, offer sources more or less extensive. From such sources are derived the water supply of Peoria, Ill., and the numerous artesian wells in the Red River Valley in Minnesota. A table submitted herewith gives some data concerning some of the larger cities and towns of the United States having underground sources of water supply.

The liability of wells or galleries adjacent to streams to receive water by infiltration from the streams varies with the nature of the deposits through which the stream flows. Within the drift belt the rivers, as a rule, carry so much silt that any outflow is at once checked by the silting of the pores in its bed. The tendency, when the adja-

Some of the Larger Cities and Towns of the United States Having Subterranean Sour

City.	State.	Population. 1890.	Source.	
Anniston	Alabama	9 998	Springs	
Appleton	Wisconsin	11 869	3 artesian wells	St. Pete
Akron	Ohio	27 601	Artesian wells	
Atlantic City	New Jersey	13 055	Large well	
Aurora	Illinois	19 688	2 artesian wells	From St
Beloit	Wisconsin	6 315	Large well	From Tr
Big Rapids	Michigan	5 303	Drive wells	From dr
Brooklyn	New York	806 343	Drive wells	From dr
Brunswick	Georgia	8 459	Artesian wells	
Cedar Rapids	Iowa	18 020	Artesian wells	From River
Charlestown	South Carolina	60 000	3 artesian wells	
Clinton	Iowa	13 619	4 artesian wells	From Po
Columbus	Ohio	88 150	Filter gallery	From dr
Dayton	Ohio	61 220	65 8-in. tube wells	From dr
Des Moines	Iowa	50 093	Large well	
Dixon	Illinois	5 161	2 artesian wells	From Po
Dubuque	Iowa	30 311	Artesian wells	From Po
Fond du Lac	Wisconsin	12 024	5 artesian wells	From St
Freeport	Illinois	10 189	18 drive wells	From dr
Fresno	California	10 818	10 Artesian wells	200 to 60
Galena	Illinois	5 635	Artesian wells	From Po
Galesburg	Illinois	15 264	Drive wells	From dr
Grand Island	Nebraska	7 536	Drive wells	Platte R
Jamestown	New York	16 038	Artesian wells	
Jackson	Michigan	20 798	Artesian wells	
Joliet	Illinois	23 264	Drive and artesian wells	From dr
Jacksonville	Florida	17 201	4 artesian wells	From cr
Kearney	Nebraska	8 074	Drive wells	Platte R
Kalamazoo	Michigan	17 853	2 large wells	From dr
Lincoln	Nebraska	58 000	2 large wells	From dr
Macon	Georgia	22 746	Springs	
Memphis	Tennessee	64 495	Artesian wells	From cr
Mansfield	Ohio	13 473	16 wells, 2 springs	From dr
Montgomery	Alabama	21 883	Artesian wells	
Michigan City	Indiana	10 776	Springs	From dr
Muncie	Indiana	11 345	Artesian wells	
Manistee	Michigan	12 812	50 drive wells, 1 large well	From d
New Brighton	New York	16 423	76 drive wells	From d
Nashville	Tennessee	76 168	Underflow	Cumber
Oshkosh	Wisconsin	22 836	Artesian well	Lake Wi
Peoria	Illinois	41 024	Large well	From gr
Pine Bluff	Arkansas	9 952	Drive wells	
Pensacola	Florida	11 750	16 drive wells	
Pittsburgh	Kansas	6 697	Artesian wells	
Rockford	Illinois	23 584	9 artesian wells	From F
Savannah	Georgia	43 186	Artesian wells	
Stockton	California	14 424	Artesian well	
Selma	Alabama	7 622	3 artesian wells	
South Bend	Indiana	21 819	32 artesian wells	From d
Springfield	Illinois	24 963	Well and filter gallery	From d
Sioux City	Iowa	45 000	Drive wells	
Winona	Minnesota	18 208	2 large wells	Mississ

United States Having Subterranean Sources of Wate

Population. 1890.	Source.	Geological Sou
9 998	Springs	
11 869	3 artesian wells	St. Peter sandstone.
27 601	Artesian wells	
13 055	Large well	
19 688	2 artesian wells	From St. Peter and Potsda
6 315	Large well	From Trenton rock.
5 303	Drive wells	From drift.
806 343	Drive wells	From drift.
8 459	Artesian wells	
18 020	Artesian wells	From Pottsdam Sandsto River for fire service.
60 000	3 artesian wells	
13 619	4 artesian wells	From Potsdam and St. Pet
88 150	Filter gallery	From drift.
61 220	65 8-in. tube wells	From drift.
50 093	Large well	
5 161	2 artesian wells	From Potsdam sandstone.
30 311	Artesian wells	From Potsdam sandstone.
12 024	5 artesian wells	From St. Peter sandstone
10 189	18 drive wells	From drift.
10 818	10 Artesian wells	200 to 600 ft. deep.
5 645	Artesian wells	From Potsdam sandstone.
15 264	Drive wells	From drift.
7 536	Drive wells	Platte River Valley.
16 038	Artesian wells	
20 793	Artesian wells	
23 264	Drive and artesian wells	From drift and St. Peter
17 201	4 artesian wells	From cretaceous strata.
8 074	Drive wells	Platte River Valley.
17 853	2 large wells	From drift.
58 000	2 large wells	From drift.
22 746	Springs	
64 495	Artesian wells	From cretaceous strata.
13 473	16 wells, 2 springs	From drift.
21 883	Artesian wells	
10 776	Springs	From drift.
11 345	Artesian wells	
12 812	50 drive wells, 1 large well	From drift.
16 423	76 drive wells	From drift.
76 168	Underflow	Cumberland River, from
22 836	Artesian well	Lake Winnebago, for fire
41 024	Large well	From gravel in ancient bed
9 952	Drive wells	
11 750	16 drive wells	
6 697	Artesian wells	
23 584	9 artesian wells	From Potsdam and St. P
43 186	Artesian wells	
14 424	Artesian well	
7 622	3 artesian wells	
21 819	32 artesian wells	From drift.
24 963	Well and filter gallery	From drift.
45 000	Drive wells	
18 208	2 large wells	Mississippi underflow.

L SOURCE.

Potsdam sandstone.

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St. Peter sandstone.

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d St. Peter sandstone.

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cent ground-water is low, is for the water of the stream to flow into the ground, and the reverse when the ground-water is high. This has undoubtedly resulted in making the beds of streams within the drift area practically impervious, and little permanent infiltration can be expected into wells or filter galleries from such sources. From this condition has resulted the failure of such wells and galleries as have been sunk near streams, with the expectation of obtaining filtered river water.

Outside of the drift area, however, the streams are often more free from silt, and flow in beds of sand. In such cases the visible stream is but a portion of the invisible stream, flowing under and on both sides parallel to it. Such a stream is the Platte River of Colorado and Nebraska, and during dry weather, when the visible Platte shrinks to little or nothing, water can be obtained by digging into its sandy bed. It is, of course, obvious that a filter gallery or well near such a stream will receive water filtered through the adjacent banks. Nashville, Tenn., obtains its supply from a filter gallery in a sandy island in the Cumberland River.

The seepage of water into and from the adjoining ground is shown in a series of gaugings of the South Platte River, in Colorado, a record of which from the report of the State Engineer is submitted on page 700.

The dependence or independence of a supply on the conditions of rainfall on its water-shed depends entirely on the nature and extent of such water-shed. Where the water-shed is extended and abounds in lakes, swamps and rivers, little or no change will be noticed at different seasons. The Potsdam sandstone, for example, has an outcrop in the upper Mississippi valley of about 14 000 sq. miles, over which flow numerous rivers. Hence supplies derived from this source feel comparatively little influence of temporary conditions of rainfall. On the other hand, with limited water-shed the influence is immediate; as an example of this may be mentioned the artesian wells at Denver, Colo. Mr. Wadsworth, of Arvada, Colo., says of these wells (see Preliminary Report of Artesian Well Investigation, Department of Agriculture, 1890, page 180): "Our artesian wells come and go with the seasons. When the little streams in the foothills are pouring their contents into the loose rocks * * * artesian wells in Denver and vicinity work all right; but when the streams fail in the foothills, some of the wells cease to flow."

TABLE OF MEASUREMENTS OF SEEPAGE WATER IN THE SOUTH PLATTE RIVER, COL., OCTOBER 23D TO NOVEMBER 5TH, 1891.

From Sixth Biennial Report, State Engineer of Colorado.—In Feet per Second.

Names of Streams and Ditches where measurements were taken.	Amount of water in river.	Amount of water diverted from river by irrigation ditches and canals. From last station.	Amount of inflow from natural tributaries.	Amount of water in river at points measured, plus that diverted by canals and minus the inflow from natural tributaries.	Amount of increase in volume of river between points measured.	Decrease in volume of river between points measured.	Miles between points measured.	Amount of increase per mile between points measured.	REMARKS.
South Platte River	204.35								Above dam of High Line Canal.
" "	46.16	185.76		231.92	27.57		6	4.93	Below City Ditch.
Plum Creek			2.98						
South Platte River	84.86	16.89		284.53	53.61		6	8.93	At Littleton.
Bear Creek			7.26						
Cherry Creek			5.59						
South Platte River	90.05	23.86		300.73	16.20		10	1.62	At foot Sixteenth Street, Denver.
Clear Creek			1.04						
South Platte River	79.58	53.98		343.20	42.47		11	3.86	Below Fulton Ditch.
" "	73.96	41.96		379.54	36.34		7	5.19	Below Brighton Ditch.
" "	90.28	27.18		423.04	43.50		9	4.83	Below Evans No. 2 Ditch.
" "	11.09	87.43		431.23	8.14		7	1.16	Below Farm's Ind. Ditch.
" "	17.48			437.67	6.39		5	1.29	Above St. Vrain Creek.
St. Vrain Creek			28.94						
Big Thompson Creek			12.85						
South Platte River	87.68	37.48		503.56	65.89		11.5	5.73	Below Latham Ditch.
" "	114.60			530.48	26.92		6	4.49	Above Cache la Poudre River.
Cache la Poudre River			61.11						
South Platte River	244.33			607.01	76.53		9	8.50	Below Harding Ditch.
" "	211.69	49.25		623.21	16.20		11	1.47	Below Putnam Ditch.
" "	106.69	120.28		638.40	15.29		14	1.09	Below Ft. Morgan Canal.
" "	134.81	10.14		676.76	38.36		9	4.37	Below Platte and Beaver Ditch.
" "	186.79	46.21		774.95	98.19		14.5	6.77	Above Smith Ditch at Snyder.
" "	46.68	119.84		754.68		20.27	17.5	Loss 1.16	Above Merino.
" "	66.73	13.31		788.04	33.36		13	2.59	At Sterling.
" "	52.72	42.08		816.11	28.07		9	3.12	At Iliff.
" "	39.65			803.04		13.07	15	Loss 0.87	Two miles above Crook.
" "	47.70			811.09	8.05		20	3.42	Below Sedgwick.
" "	42.96			806.35		4.74	16	Loss 0.29	At Julesburg. Average increase per mile = 3.24.

B. SALBACH.—In writing this paper it was not my intention to give a technical description of the mechanical appliances used for obtaining potable water from subterranean sources, but only to show and explain the existence of underground sources and their subterranean courses. The different methods employed for obtaining the water from these sources depend on the geological formation and the extent of the subterranean water-bearing strata. In the case of thin and small pervious strata horizontal collecting galleries are used, while larger masses of gravel and debris filling the subterranean valleys are opened for supply by putting down wells. Where the water-bearing soil shows a very compact stratification, it is advisable to put down a great number of wells of small diameter—150 to 200 mm. (6 to 8 ins.), while a loose and very pervious character of the subterranean strata calls for wells of larger diameter—5 to 7 m. (16 to 23 ft.).

On this subject, as well as the results attained in the new waterworks of the cities of Vienna and Dresden, there are publications to be found in technical journals. In the meantime I am gratified to find that my paper has given rise to so instructive a discussion.

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684.

(Vol. XXX.—December, 1893.)

PURIFICATION OF SEWAGE AND OF WATER BY FILTRATION.—DISCUSSION ON PAPER No. 650.*

By EDWARD FLAD, ALLEN HAZEN, RUDOLPH HERING, THOS. M. DROWN, G. H. BENZENBERG, ROBERT MOORE and E. C. JORDAN.

EDWARD FLAD, M. Am. Soc. C. E.—I would like to ask a question in connection with the paper of Mr. Mills on purification of sewage. I presume Mr. Hazen can set me right. Some months ago, I had occasion to look over these reports. In the reports covering the purification of sewage through gravel beds, I found that at the end of the third year the gravel was unchanged, and that they succeeded in filtering about 100 000 galls. per acre in 24 hours. It was stated that filtration could be carried on for an indefinite period without the necessity of cleaning the gravel. I went on, and the next year, I think the fourth year of the experiments, the gravel bed was found to be slimy, and it was evident that it would be necessary to remove a portion of the gravel. My reading of those reports does not quite agree with the extracts from Mr. Mills' paper.

ALLEN HAZEN, Assoc. Am. Soc. C. E.—The paper states that there is a certain small percentage of nitrogenous matter in sewage which is

* "Purification of Sewage and of Water by Filtration." By Hiram F. Mills, A. M., C. E. *Transactions*, Vol. XXX, page 350.

stored in sand in any case; Mr. Mills gives it as 15% of the total amount. In the case of sand, this is stored in the surface layer where it can be seen, but in the case of large gravel stones the movement of the sewage over the stones carries this material below the surface to a point where the current is so slow that it has a chance to deposit itself upon the stones. There is no surface indication of what has accumulated. At the end of a certain time this material had accumulated to such an extent that it prevented the circulation of air through the slime; oxidation was prevented, and we got simply a straining.

Mr. FLAD.—I would like to have an explanation in regard to the direct statement which was made at the end of the third year, that the gravel could be used indefinitely for a number of years, while I thought that a directly contrary statement was made in the next report, and I was much disappointed. I would like to know what the final result is.

Mr. HAZEN.—The result? At the end of the time that you mention there was no appearance of clogging; the material, so far as we could get at it, was entirely clean; we did not know of the accumulation below the surface.

Mr. FLAD.—The extracts which were read a few minutes ago from Mr. Mills' paper did not refer to any such clogging. Upon referring, however, to his paper, which I had not previously had an opportunity of reading, I see that he fully explains the matter. The fact that the conclusions at the end of the fourth year should directly contradict those given out the year before is somewhat discouraging, and naturally gives rise to a doubt as to how far the present conclusions, as to the capacity and life of filter beds, may be depended upon.

RUDOLPH HERING, M. Am. Soc. C. E.—Mr. President, I would like to state, in answer to the gentleman who asked a few questions, that on page 355, the paragraph beginning the 8th line from the bottom gives the answer to one of them.

"With the material best adapted to the purification of large quantities of sewage there is a deposit of nitrogenous matter in the upper layers amounting to about 15% of all of this kind of matter applied in the sewage. The other 85% is oxidized and passes off in solution as nitrates in the effluent. The effect of this deposit on and near the surface is to decrease the air space between the grains of sand and increase the amount of water continually held by these layers, thus in time preventing sufficient change of air in the layers beneath. Continued efficient action may be had by frequently raking over the surface to the

depth of 1 in.; but there comes a time when the upper inch should be removed and replaced by clean sand."

This removal seems to be required under the best conditions. Where the sand is not so perfectly adapted as in this case, the upper layer would have to be more frequently removed.

I would like to add that I consider this paper as being one of the most important that has been prepared on the subject, as it presents, I believe, for the first time to an engineering society, the results gained from these valuable experiments. Formerly, it was supposed that the purification of sewage was accomplished mainly by vegetation, *i. e.*, by plants which were supposed to extract the organic matter from the sewage, and thus purify the water. It has, however, been demonstrated by the experiments of the State Board of Health of Massachusetts that this is not the case, to any great extent, but that we must look for the purification to other means, namely, to pure, clean sand without any organic matter in it. The paper explains why, and the full reports of the Board furnish the proof. I think a marked progress has herewith been made on the subject. We still hear it said, mainly in Europe, that we must *utilize* the sewage in order to properly dispose of it. But that is not the true way to look at the question; we must *purify* it, and when we have done this we may incidentally look to some utilization, but should not consider it the first point to be aimed at. I was in hopes that we might hear from the author also something on the subject of the purification of sewage by dilution, as it is customary in nearly all of our large cities to dispose of the sewage by introducing it into a large body of water. It has been stated in England that sewage will purify itself by flowing a certain distance in a large stream. Some years ago I made a careful investigation of this subject, but failed to find any definite or reliable information. It seemed to me that what was thought to be purification was merely a greater dilution of the sewage by the added quantities of water entering the stream further down. My examinations of several American and European rivers showed that the quantity of albuminoid ammonia contained in the water was almost in proportion to the quantity of pure water that was added to the river. There appeared to be, however, a slight actual purification, probably due to the bacteria that are always present in river water. For all practical purposes this purification seems insignificant; yet, I would like to see some board or some corporation

make the necessary experiments to throw further light on the subject of sewage dilution.

There is another important question which appertains to the general subject, namely, the purification by the addition of chemicals. We have at the World's Fair a plant which receives all the sewage from the grounds, about 2 000 000 galls. a day, I believe. This quantity is received and delivered into several tanks, where it receives certain chemicals, which precipitate the suspended matter, the effluent water running off into the lake. The general system of precipitation was first introduced in England and since then has been introduced in several cities of Europe, and also in our country. The particular appliances used here are of German invention. I was a little surprised to learn of the present result. It seems that occasionally the number of bacteria has been increased, and that the addition of the chemicals does not remove much more than one-half of the organic matter contained in the sewage. Most of the suspended matter is removed, but the organic matter held in solution, which is of course just as objectionable, seems to be left in it.

Mr. HAZEN.—In regard to the treatment of sewage at the World's Fair, I would say that the quantity of sewage is from 2 000 000 to 3 000 000 galls. per day, and under favorable conditions we are removing 60% of the organic matters of the sewage; at other times when the flow is excessively irregular, owing to the action of the Shone ejectors, the percentage is sometimes reduced even below 50 per cent. The removed matters consist of suspended insoluble matters; hardly any of the soluble matters are precipitated. In regard to which of the two forms is most objectionable: We have one problem where a nuisance is caused by sewage forming deposits which decompose and give off offensive odors, as in the Chicago and Milwaukee rivers. We have another problem which is entirely different, and which must be reached in different ways, where sewage is running into drinking water, causing disease. Where it is a question of forming deposits, and producing bad odors; then removing the suspended matters from the sewage will reduce those dangers I think much more than the total reduction of organic matters.

Dr. THOS. M. DROWN.—It is not fair, I think, to say that the statements in the recent reports of the Massachusetts State Board of Health contradict the statements made in the previous reports with regard to

the capacity of soils for the purification of sewage. Each year's work adds to our knowledge of the subject, and gives us information that can only be obtained by additional years' experience with the filters. The experience of two years suggested the probability of the indefinite use of a filter for the purification of sewage, without the renewal of any of the sand. Additional experience shows us that with high rates of application of sewage the accumulation of fine sludge may shut out the air more or less completely from the filter, and retard or prevent oxidation. The remedy in such case may be smaller applications of sewage, a period of rest, or the removal and replacement of the surface layer of sand. On the large scale, with ample areas, which permit the frequent resting of the beds, it would probably never be necessary to remove the surface sand.

With regard to the question whether a sewage disposal area could be made to purify an amount of sewage equal to the amounts indicated in the Lawrence experiments, I would say that they could if they were conducted with equal care and judgment. But this is not to be expected on the large scale. In the forthcoming report of the Board this point receives due consideration, and it is said that in regular practice we cannot expect the process of sewage purification to be carried on with the scientific supervision which is given to the experimental filters at Lawrence.

It must be borne in mind that the Lawrence work is purely experimental. We are studying the problem on a large scale by laboratory methods, and with the highest scientific precision, in order that we may learn the nature of the process and determine its applicability under varying conditions to the purification of sewage on a large scale.

G. H. Benzenberg, M. Am. Soc. C. E.—It seems to me that the experiments which have been made at Lawrence by the State Board of Health do determine that sewage can be purified by the processes of intermittent filtration. If a plant is designed with that view of disposing of the sewage, the engineer must be careful not to admit the sewage too fast upon the filtration beds, thereby clogging the action of Nature, but must make allowance for a sufficient surface of filtering beds to permit Nature to do its work in an easy way, without clogging or obstructing. At Lawrence, undoubtedly, the experimental corps have been able to obtain larger results than would be obtained under ordinary conditions. It seems to me it would not be wise to follow

the proportions that have been used at Lawrence, but to allow a larger filtration area of sand when considering the question of the disposal of sewage by a filtering plant. Those experiments seem to demonstrate that the work can be done in that manner, as it will be done everywhere by the forces of Nature, if the danger of clogging or overcharging the areas is not allowed.

ROBERT MOORE, M. Am. Soc. C. E.—I cannot refrain from adding my testimony of appreciation to the extraordinary value of the experiments, the results of which are recorded in the paper by Mr. Mills. I think there is no question but that the experiments here recorded, made under the auspices of the Massachusetts State Board of Health, exceed in value all that have been made before anywhere. They have advanced our knowledge from uncertainty and doubt to a condition of positive certainty. The value of these researches is increasing every day. A large number of towns in our country are finding it necessary to take steps to purify, not only their sewage, but their water supply, and the knowledge gained by these researches of the different methods in which this can be done places the whole country in debt. I cannot, moreover, help feeling a sense of regret that these researches had not been made somewhat earlier, or if not, that the steps which the city of Chicago is now taking to further pollute the Illinois River had not been for a few years deferred. To those of us who live on this river, or below its mouth, this work which Chicago is now doing causes much solicitude. The pollution of this river, which is due in part to the towns along its banks, but primarily to the sewage already poured into it by Chicago, is yearly becoming greater, and, in low water, is distinctly traceable in the Mississippi below the mouth of the Illinois. In fact, we begin to suspect that St. Louis is indebted to this cause for a large part of its typhoid fever. But be this as it may, to break through a natural divide in order to pollute the water of a foreign stream, as Chicago is now doing, and preparing to do in much greater degree, is a step which can be justified only by overwhelming and absolute necessity. The facts set forth by Mr. Mills, however, afford a complete demonstration that, by filtering its sewage or its drinking supply, or both, Chicago could have protected itself without resorting to the unusual, not to say unnatural, means to which it has in fact resorted. I repeat, therefore, my regret that this demonstration had not come a little earlier, or the action of Chicago been a little longer delayed.

Mr. HERING.—I might answer this remark by stating that even if the results had been known it would not have made any difference in the plan for disposing of the Chicago sewage; enough was known to reach a safe conclusion in that case. England has purified sewage for 30 or 40 years by filtration, and has given us a great deal of practical experience as to what could be done by it. Mr. Bailey Denton has advocated intermittent filtration since the year 1875, or perhaps earlier, and based the same on results obtained by Dr. Frankland. I think it is due to Mr. Denton to state that the practical success of intermittent filtration was first accomplished by him. We knew all this at the time the investigation was made here in Chicago, and I might add that the estimated cost of purifying the sewage by this means was found to require the expenditure of something like $60 000 000. There is no sand in the immediate neighborhood of Chicago that is fit for the purpose. It would have been necessary to build large sewers to the southern end of Lake Michigan and then prepare the sand dunes which are found there, and convert them into filter beds. The estimated cost was about $60 000 000, and that put the adoption entirely out of question.

Mr. E. C. JORDAN.—I think we owe a great debt to Massachusetts for lifting us out of the condition that we were put into as to the utilization of sand by a former National Board of Health. I recollect the papers that were written at that time, stating quite graphically the way in which the sand was used or experimented with, that it offered no resistance whatever to the passage of bad germs, and that we were not at liberty to consider it a method or means of filtration. We have, however, gone back to the old rules of Nature that we have seen going on in every little stream and water supply. We have wondered if the results which were given to the public in that report were true. Now comes the Massachusetts Board of Health and tells us that we were originally right and they have established a formula for it. At the most, it is simply the formula of what we have always observed. I feel quite gratified at being able to go back to the original ideas that we have been educated in by Nature, and we now can reasonably expect good work from the results indicated and approved by the Massachusetts Board.

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685.

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THE SEWERAGE SYSTEM OF MILWAUKEE.—DISCUSSION ON PAPER No. 651.*

By D. J. WHITTEMORE, F. P. STEARNS and G. H. BENZENBERG.

D. J. WHITTEMORE, Past. Pres. Am. Soc. C. E.—I wish, as coming from Milwaukee, to make some remarks upon the paper by Mr. Benzenberg. I wish to call the attention of this Congress to the condition of the Milwaukee River before the work of flushing commenced, and which the writer of this paper, through his natural modesty, has not adequately emphasized. Along several miles of the river many of the best and most extensive mercantile and other establishments are located, covering the ground between the shore and adjacent streets completely. Into the river was flowing 60% of the sewers of a city of 200 000 population, and of course the river was foul. This is a mild term. It was so filthy from noxious and nauseating exhalations that I venture to say Chicago River would be termed clean in comparison. A person could not pass over it without having a feeling of nausea. Occupants of the buildings were made ill. Removals from its banks were contemplated by many, and real estate in its proximity depreciated in value.

* "The Sewerage System of Milwaukee, and the Milwaukee River Flushing Works" By G. H. Benzenberg, M. Am. Soc. C. E. *Transactions*, Vol. XXX, page 367.

While the people universally demanded a remedy, a majority had little faith in the plan proposed by the writer of the paper under consideration. Having had some experience with centrifugal pumps, and knowing the general dimensions of the work proposed, I myself had grave doubts of its success. I knew the duty developed by the Bridgeport pumps in this city, and pumps of like nature used to drain marshes in Italy; hence I came to the conclusion that with no greater duty and efficiency than those, the project proposed by the writer of the paper under consideration would prove a failure. What was the result? Within one day after starting the work the nuisance was completely abated, through the agency of pumps and machinery which developed a duty of about 76 000 000 ft.-lbs. per 100 lbs. of coal used, being quite double the duty developed by any pumps of somewhat similar nature of which I then had or now have knowledge. Informing a distinguished German engineer who had made machines of this nature a subject of careful inquiry (Edward Hamberle, of Carlsruhe) of the result of this work, he replied that the people of Milwaukee had the most efficient centrifugal pump in the world. It is not often that the engineer's work is so heartily appreciated within 24 hours after its completion as was that of the writer of the paper under consideration, by the people of Milwaukee.

In this connection it may be proper to ask why the city of Chicago, whose authorities naturally must have known of the existence of this pump and of its remarkable efficiency, has recently attempted to employ an untried device for a similar purpose, which attempt, as I am reliably informed, has resulted in lamentable failure.

F. P. Stearns, M. Am. Soc. C. E.—I wish to express my appreciation of the value of Mr. Benzenberg's paper. It is a very complete and concise description of a very interesting system of works. I have been particularly interested in the centrifugal and screw pumping machinery at Milwaukee, both on account of the large capacity of the pumps and the high duty obtained with them. The duty obtained with the centrifugal pump is, so far as I know, much higher than was ever before obtained with a pump of this character, and the results have raised this class of machinery very much in my estimation, for sewerage works, where as a rule only a low lift is required. In large works there is a very great saving in the first cost of foundations and pump wells as well as machinery by using centrifugal instead of reciprocating pumps.

In making preliminary estimates of the cost of the new metropolitan system of sewerage for the cities and towns in the vicinity of Boston, it was found that it would be very much cheaper to put in two pumping stations on the line of the main sewer, lifting the sewage one-half of the total height at each, with centrifugal machinery, rather than to pump to the full height with reciprocating engines at a single pumping station. The use of two pumping stations in this case was particularly advantageous, because it permitted the sewer (about five miles long) between them, to be laid at a moderate depth below the surface of the ground instead of at a very great depth. It is worthy of note, however, that the estimated cost of the two pumping stations with centrifugal machinery was much less than the cost of a single station with twice the lift, provided with reciprocating pumps.

G. H. BENZENBERG, M. Am. Soc. C. E.—In connection with the expense of forcing the water through the flushing tunnel, that question having been asked, I found it was not very much more than that of a high duty water-works pumping engine, that is, about 3¾ cents or 3.78 cents per 1 000 000 galls. per foot. That is, upon a basis of using the best quality of hard coal, which cost, say, $5 15 to $5 25 per ton, delivered at the station. That quality of coal is used because the pumping station is situated in one of the finest residence sections of the city; where, if soft coal were used, the people would object. It makes the cost of pumping of course much higher than if a cheaper grade of coal were used.

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686.

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THE NORTH SEA CANAL OF HOLLAND.—DISCUSSION ON PAPER No. 652.*

By J. FÜLSCHER, R. W. LESLEY, THEODOR REHBOCK and W. R. HUTTON.

Mr. GLEIM (translating remarks by Mr. J. Fülscher).—Mr. Fülscher would like to ask a few questions. On page 399 (Vol. XXX), the author says that on completing the foundations of the locks the layer of concrete, which was 2.5 m. high, had been covered with 2 m. of sand. Mr. Fülscher would like to ask why this was thought necessary or advisable, and whether it would not have been as well to allow the concrete to harden under water, without covering it with the sand.

In the second place, Mr. Fülscher refers to the fact that for the mixing of the concrete the author specified two-thirds of the broken brick material to be hard-burned, or else rock, granite or other hard natural stone, and says that he does not see the reason for this, and asks whether it might not have been as well to use ordinary brick. Considerations of specific gravity have apparently not been the cause, or else the broken bricks would not have been admitted at all. It must therefore be inferred that the specifications were induced by considera-

* "The Enlargement and Improvement of the North Sea Canal of Holland (Amsterdam Ship Canal)." By A. E. Kempees, C. E., Royal Engineer in Holland. *Transactions*, Vol. XXX, page 386.

tions of greater crushing strength; but it is not apparent why this case should have required a more than ordinary amount of crushing strength.

R. W. LESLEY, Assoc. Am. Soc. C. E.—In reply to Mr. Fülscher as to this point, I would state that possibly the reason for using hard-burned brick clinker rather than the ordinary light-burned brick in making concrete was the fact that where concrete is made of light-burned brick the brick absorb the water very rapidly from the concrete, ultimately causing the disintegration of this latter.

In Philadelphia there was recently a case of this kind where a large amount of concrete was made of brickbats, cement and sand. This was done in hot weather, and the brick absorbed the water from the cement mortar so rapidly that in a short time after the work was done it all began to fall away, and the piers had to be rebuilt. For this reason, no doubt, the specification was made requiring the use of hard-burned brick clinkers rather than soft-burned brick.

Mr. GLEIM.*—Mr. Fülscher states that if the hard material had been specified from a fear of the brick absorbing too much water from the mortar in mixing the concrete, he does not agree with this view, especially in a case where the concrete was deposited under water.

For a third question, Mr. Fülscher refers to the fact mentioned on page 400, that springs were found in the soil when the concrete was being put in, and that the places of these springs were just where the bore holes to test the soil had been made. He asks if that could not have been avoided by making the bore holes around the site of the lock instead of inside. As the author is not here, that is a question which could hardly be answered by an outsider.

THEODOR REHBOCK replied in German (translated by Mr. Gleim) that he happened to know from one of the engineers of the work that the bore holes were not made for this canal, but had been made for other work before this line of canal had been settled; it was a mere accident that this lock happened to come in this place.

Mr. GLEIM.*—Mr. Fülscher says he has had a similar experience in his work, which is the great North and East Sea Ship Canal in Germany, at places where the bore holes had been made at a time when the situation of the lock was not finally fixed. The speaker quotes the means they took in treating these springs. The paper says they had allowed

*Translating Mr. Fülscher's remarks.

the water to rise to a moderate amount only before putting in the concrete. He asks whether they could not have allowed it to rise to a greater height, so as to balance the pressure of the springs and have no movement of the water at all. By this means they might possibly have avoided the troubles which they afterwards had on this account, because the concrete was washed out by the springs.

Then, after those springs had given trouble, the damaged concrete was taken out at those places, and large standpipes put in, with flanges underneath, which were embedded from the outside in concrete. Mr. Fulscher thinks it would have been better to have taken this measure from the beginning and inserted those pipes before putting in the concrete as they have always done in similar cases on his work.

He further discusses the plan of closing up those pipes with concrete as the work proceeded, and asks why this was thought necessary, and whether it would not have been better to have left them open, because in case the lock is ever pumped out for the sake of repairs, he thinks those closed-up pipes may be dangerous, unless the floor of the lock be considered strong enough to withstand the pressure of those sealed-up springs against the concrete bottom.

W. R. Hutton, M. Am. Soc. C. E.—There are numerous points of interest connected with the North Sea Canal and its harbor works.

First may be noted the great efficiency of a wide, thin platform of rip-rap under the pier walls. The work has commenced, as stated by Mr. Kempees, by laying the concrete blocks directly upon the sand, where they were promptly undermined, and the entire work accomplished was threatened with destruction.

After this a platform of small rubble (rip-rap) was established about 100 ft. in width and 3½ ft. thick. The pier walls built upon it with a width at base of 20 to 27 ft. have never been disturbed, and Mr. Darnton Hutton (engineer of the contractors who constructed the works) informs me that no displacement of the rip-rap has ever been observed. It is true that the outer half of the length of the piers which is exposed to the heavier seas is protected on the seaside by "wave breakers," concrete blocks weighing 20 tons, disposed as a rip-rap.

This foundation has since been applied in other harbor works; rarely, however, it is believed, on our own coasts. The late Mr. Henry Bacon, civil engineer for many years in local charge of the Cape Fear

River improvement, has expressed the opinion that it is the best bottom protection, even on those shifting sands.

Manora and Columbo breakwaters have been erroneously cited as instances of the above construction. Those were mounds of rubble, built up to within a few feet of the water-surface and surmounted by a masonry wall. The basalt bed at Ymuiden is purely a foundation work; its purpose is to protect the base of the wall and prevent undermining by scour. In 1878 it was observed that the earlier concrete blocks were much worn by the action of the sea. Those made later with a larger proportion of cement, although they had been exposed for two years to the action of very heavy waves, still retained the sharpness of their angles. From Mr. Kempees' paper it is inferred that these, too, have suffered with lapse of time.

A second point of interest is the large quantity of sand brought into the harbor by the tide. The original plan of the harbor provided an elliptical basin occupying nearly all the space inside the piers, in which ships could lie at anchor. It is probable that much of the dredging of the earlier years after completion was done in the effort to make this basin. In 1878 it was said at the works that, although the flood current split on the North Pier Head, but little sand was brought in. The late Mr. Dirks, chief engineer of the works in 1883, spoke most discouragingly of the large deposits as a somewhat recent discovery.

The flood tide sweeps along the coast of Holland, northeasterly, with a velocity of 2¼ to 2½ miles an hour—about 4 ft. a second; the ebb current is much weaker, and is not parallel with the coast line. At the Hook of Holland the bottom currents vary much in direction from those of the surface for some time before and after either turn of the tide. The heaviest storms are from the northwest.

The deposit is apparently not caused by the movement of the sands along the beach as was predicted by Croizette de Noyers in 1873, for the angle of the pier with the beach is not filled up, the depth curves are not pushed farther out, and there is a scour along both the canted or oblique portions of the harbor walls. The large deposits inside the harbor would seem to come from sand carried in suspension by the strong flood current and dropped in the quiet water inside the pier.* Their principal location along the inside of the north pier is further

* See, also, Mr. Harrison Hayter in Proceedings, Inst. C. E., Vol. LXII.

evidence that the flood current splits on the north pier and enters with considerable velocity.

Sir John Hawkshaw who designed the harbor, at a later period maintained that an artificial harbor in the sea in strong littoral currents, as in the English Channel and at this place, should have a long front parallel with the shore line, with the entrance in the middle of its length, as then proposed for the harbor of Dover and since applied in the new harbor of Boulogne. He is quoted as having said that the Ymuiden harbor was not designed on this plan because there were not sufficient funds at his disposition.

No experiments are known to have been made to ascertain the amount of sand carried by these currents, or others in similar conditions. Roughly computed from the dredgings it would appear to be here about $\frac{1}{700}$ of their volume. The Mississippi River in flood carries silt to about $\frac{1}{1800}$ of its volume. In the estuary of the Seine, currents of 10 ft. per second, rushing over shallow banks of silt, take up at times $\frac{1}{130}$ of their volume of light material, although the average for a flood tide is something less than $\frac{1}{1800}$ by volume.

The following suggestion is made with diffidence, for want of local knowledge, observation and experience:

The general maximum velocity of the tidal water in the entrance, due only to the rising of the tide, would be 0.3 ft. per second. If a portion of the flood tide current enters with a velocity of 3 or 4 ft. per second, some of it must flow out again through the entrance, either at the bottom or around the south pier head, for the water in the harbor cannot be sensibly higher than that outside. If this be so, the deposits come from the material carried in suspension by a much larger quantity of water than would fill the harbor to high-water line. If the flood current can be prevented from entering with velocity beyond that actually necessary to fill the basin, the quantity of deposit will be largely reduced.

The scour along the canted arms of the harbor walls seems to indicate that the mass of water nearer the shore, obstructed by the piers, flows with greater velocity along the south cant, crosses the entrance, a portion being deflected into the harbor, and follows along the north cant into the otherwise quiet water north of the harbor. This would probably have been different if the wall north of the entrance had been continued parallel with the sea current, even for a short

distance. If all this be true, it does not necessarily follow that it should be corrected now. The cure may be more expensive than the disease.

The project of Mr. Huet for an open canal from the North Sea to the Zuider Zee is not sufficiently described in his paper.

It has elicited much discussion in the Netherlands Society of Engineers, and a project has been prepared which it would be of great interest to discuss. Some lively currents would probably be inaugurated, owing to differences of tidal levels in the two seas, and it would be of interest to consider their effect upon the silting of the harbor.

The bar, off the entrance, mentioned by M. Quinette de Rochemont, may be composed of the material scoured from the base of the south cant, or it may be formed by wave action normal to the shore line.

LIST OF PAPERS PRESENTED TO DIVISION A, INTERNATIONAL ENGINEERING CONGRESS, IN CHARGE OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

PAPERS PRESENTED AND PUBLISHED.

"Navigation Works Executed in France from 1876 to 1891."
By F. GUILLAIN, Inspecteur-Général des Ponts et Chaussées, Paris, France, xxix, p. 1.

"Inland Transportation."
By Capt. F. A. MAHAN, Corps of Engineers, U. S. A., xxix, 97.

"History of the Conversion of the River Clyde into a Navigable Water-Way, and of the Progress of Glasgow Harbor from its Commencement to the Present Day."
By JAMES DEAS, Engineer Clyde Navigation, xxix, 128.

"Description of the Lower Weser and its Improvement."
By L. FRANZIUS, Ober-Bau-Director, Bremen, Germany, xxix, 173.

"A Brief Account of the Building of Leixões Harbor."
By ALFONSO JOAQUIM NCGUEIRA SOARES, Portugal, Inspecting Engineer in Charge, xxix, 194.

"The Limits Attainable in Improving the Navigability of Rivers by Means of Regulation."
By H. ENGELS, Professor of Hydraulics in the Royal Technical High School, Dresden, Germany, xxix, 202.

"The Improvement of Harbors on the South Atlantic Coast of the United States."
By WILLIAM MURRAY BLACK, Captain Corps of Engineers, U. S. A., xxix, 223.

"The Rearrangement of Railroad Tracks and Stations in Cologne, Prussia."
By F. LOHSE, Eisenbahn Bau und Betriebs-Inspector, Cologne, Prussia, xxix, 277.

"The Rearrangement of the Railway Terminal System at Altona, with Special Reference to the Avoidance of Grade Crossings."
By R. CAESAR, Regierungs und Baurath, Member of the Royal Board of Railroad Directors, Altona, Prussia, xxix, 295.

"Common Roads, Railways and River Communications in Portugal."
By FREDERICO AUGUSTO PIMENTAL, Civil Engineer, Lisbon, Portugal, xxix, 299.

"The Railway System of New South Wales."
By THOMAS FLETCHER BIRRELL, Civil Engineer, Newcastle, New South Wales, xxix, 326.

"Railroads in the Republic of Mexico in 1893."
By E. PRIETO BASAVE, M. Association of Engineers and Architects of Mexico, xxix, 357.

"Study Upon Railroads to Connect Guadalajara with the Pacific Ocean."
By S. V. PASCAL, M. Association of Engineers and Architects of Mexico, xxix, 373.

"Distinctive Features and Advantages of American Locomotive Practice."
By DAVID L. BARNES, M. Am. Soc. C. E., xxix, 385.

"Comparison of Modern Engine-Loading with Standard Specifications for Spans from 10 to 200 Ft."
By C. D. PURDON, M. Am. Soc. C. E., xxix, 426.

"Surveys for Railway Location."
By F. A. GELBCKE, Engineer of Government Railways, Cologne, Prussia, xxix, 429.

"A New Method of Calculating Cross-Sections of Roads and Railroads."
By FRANCISCO DA SILVA RIBEIRO, Director of Public Works, Aveiro, Portugal, xxix, 447.

"On the Gauges of Railroad Track in General, with Special Consideration of Narrow-Gauge Railroads."
By E. A. ZIFFER, C. E., Vienna, Austria, xxix, 453.

"Railway Signaling."
By G. KECKER, Betriebs-Director Imperial Railways, Metz, Germany, xxix, 491.

"Transmission of Power in Operating Cable Railways."
By ROBERT GILLHAM, M. Am. Soc. C. E., xxix, 543.

"The Continuous Superstructure of the Memphis Bridge."
By GEORGE S. MORISON, M. Am. Soc. C. E., xxix, 573.

"Bridge Substructure and Foundations in Nova Scotia."
By MARTIN MURPHY, M. Can. Soc. C. E.; President N. S. Inst. Sc.; Provincial Government Engineer, Nova Scotia, xxix, 620.

"Improved Method of Constructing Foundations Under Water by Forcing Cement into Loose Sand or Gravel by Means of Air Pressure."
By Fr. Neukirch, C. E., Bremen, Germany, xxix, 639.

"American Grain Elevators."
By G. Lee Heidenreich, M. Scandinavian Engineering Society of Chicago; Am. Inst. Min. Engrs.; Western Society of Engineers, xxix, 644.

"The Manufacture and Use of Paving Brick."
By Daniel W. Mead, M. Western Society of Engineers; Assoc. M. Am. Soc. C. E., xxix, 653.

"Carbon and its Uses in Electrical Engineering."
By Clarence M. Barber, C. E., M. Civil Engineers' Club of Cleveland, xxix, 680.

"The Guadalajara Electric Light Installation, Utilizing the Famous Juanacatlan Water-Falls, 28 Km. Distant from Guadalajara."
By Rafael M. de Arozarena, Mechanical Engineer, M. Am. Soc. Mech. Engrs.; M. Association of Engineers and Architects of Mexico, xxix, 689.

"The Relative Merits of Working Hoisting Machinery by Steam, Water or Electricity."
By George A. Goodwin, Senior Vice-President of the Society of Engineers; Assoc. M. Inst. Civil Engineers; Whitworth Scholar, xxix, 695.

"Practical and Æsthetic Principles for the Laying Out of Cities."
By J. Stübben, Baurath and Assistant Burgomaster, Cologne, Germany, xxix, 718.

"The Testing of Portland Cement and the Development of the Cement Industry in Germany."
By Max Gary, C. E., Berlin, Germany, xxx, 1.

"On the Manufacture and Testing of Portland Cement."
By Henry Faija, M. Inst. C. E., xxx, 43.

"Topographic Surveys."
By Herbert G. Ogden, Assistant U. S. Coast and Geodetic Survey, xxx, 62.

"Recent Experience on the U. S. Coast and Geodetic Survey in the Use of Long Steel Tapes for Measuring Base Lines."
By R. S. Woodward, C. E., xxx, 81.

"Terrestrial Magnetism in North America."
By Charles A. Schott, Assistant U. S. Coast and Geodetic Survey, xxx, 108.

"Fundamental Units of Measure."
By T. C. Mendenhall, Superintendent of the U. S. Coast and Geodetic Survey, xxx, 120.

"Historical Notes upon Ancient and Modern Surveying and Surveying Instruments."
By H. D. HOSKOLD, M. and C. E., Inspector-General of Mines, Argentine Republic, xxx, 135.

"The Treatment of Metals for Structural Purposes."
By JAMES CHRISTIE, M. Am. Soc. C. E., xxx, 155.

"A Proposed Method of Testing Structural Steel."
By ALFRED E. HUNT, M. Am. Soc. C. E., xxx, 181.

"The Use of Mild Steel for Engineering Structures."
By GEORGE C. MEHRTENS, Regierungs und Baurath, Bromberg, Prussia, xxx, 204.

"The Use of Basic Mild Steel as Material for Construction in Germany."
By C. WEYRICH, Engineer of River and Harbor Board, Hamburg, Germany, xxx, 219.

"The Plant of Maritime Commercial Ports of France."
By H. DESPRES, Ingenieur des Ponts at Chaussées, xxx, 235.

"The Development of Quay-Cranes in the Port of Hamburg."
By CHR. NEHLS, Chief Engineer of River and Harbor Board, Hamburg, Germany, xxx, 258.

"Method Used to Secure the Stability of a Quay Wall at the Port of Altona, on the Elbe, in Germany, which had Shifted its Position After Completion."
By BERTHOLD STAHL, Stadtbaurath, Altona, Germany, xxx, 284.

"Experiences Had During the Last Twenty-Five Years with Water Works Having an Underground Source of Supply."
By B. SALBACH, Baurath, Dresden, Germany, xxx, 293.

"Some Questions Concerning the Filtration of Water."
By W. KÜMMEL, Engineer of Gas and Water Works Company, Altona, Germany, xxx, 330.

"On the Distribution of Water in the City of Mexico."
By L. SALAZAR, M. Association of Engineers and Architects of Mexico, xxx, 336.

"Purification of Sewage and of Water by Filtration."
By HIRAM F. MILLS, A. M., C. E., xxx, 350.

"The Sewerage System of Milwaukee and the Milwaukee River Flushing Works."
By G. H. BENZENBERG, M. Am. Soc. C. E., xxx, 367.

"The Enlargement and Improvement of the North Sea Canal of Holland (Amsterdam Ship Canal)."
By A. G. KEMPEES, C. E., Royal Engineer, Holland, xxx, 386.

"Notes on Projects for the North Sea Canal from 1629–1893."
By A. HUET, C. E., XXX, 416.

"The North and East Sea Canal."
By J. FÜLSCHER, Member of Imperial Board of Canal Commissioners, Kiel, Germany, XXX, 421.

"The New Railway Stations at Dresden."
By C. KÖPCKE, Geheimer Finanzrath, and O. KLETTE, Baurath, Dresden, Germany, XXX, 450.

PAPERS PRESENTED BY TITLE.

"On the Possibility of Increasing the Water Supply from the Soil for Purposes of Irrigation and of Augmenting the Flow of Rivers."
By G. H. OTTO VOLGER, Ph.D., M. German Association of Civil Engineers' Societies.

"The Calculation of Railroad Bridge Stresses."
By JOHN L. P. O'HANLY, M. Am. Soc. C. E.

"The Tequixquiac Tunnel."
By LOUIS ESPINOZA, M. Association Architects and Engineers of Mexico.

"The Sewerage and Drainage of the Town of Coimbra (Portugal)."
By J. C. DACOSTA, J. DAC. COURAÇA and J. F. DE M. BESSA, Engineers, Members Society of Civil Engineers of Portugal.

"The Improvement of the Harbor of Lisbon."
By B. J. J. DE MATTOS, M. Society of Civil Engineers of Portugal.

"A Method of Making Mountain Railways Economical."
By UGO BALDINI, M. Society of Italian Engineers and Architects, Rome, Italy.

"Determination of Uniform Methods for Testing Building and Construction Materials."
By Prof. J. BAUSCHINGER, Munich, Germany.

"The Best Form of Level Book."
By A. T. WALMISLEY, M. Inst. C. E.

"On Rigid Arch and Suspension Bridges."
By C. KÖPCKE, Geheimer Finanzrath, Dresden, Germany.

"On the Desirability of a General Adoption by all Countries of a Uniform Method for the Tests of Materials of Construction."
By M. DEBRAY, Chief Engineer Ponts et Chaussées, Paris, France.

"Data and Observations of the Work under Construction for the Improvement of the Harbor of Vera Cruz."
By MIGUEL A. DE QUEVEDO, M. Association of Engineers and Architects of Mexico.

"The Channel Bridge."
By L. VIOLETTE, Fellow of the Society of Civil Engineers of France.

"Les Ports de Mer dans l'Archipel des Asores."
By T. V. MENDES GUERREIRO, M. Society of Civil Engineers of Portugal.

"National Railroad of Tehuantepec."
By MANUEL RIVERA, M. Association of Engineers and Architects of Mexico.

"The Sanitary Problem of Chicago."
By L. E. COOLEY, C. E.